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ABSTRACT

The present study compared learning in individual and small group settings, accounting for differences between conditions as partly a function of student ability and group process. The study had two parts. Part One provided a comparison of learning in individual and group settings. Students in Part Two performed two tasks, both in individual settings. In Part One, 11th-grade students of average and superior ability were assigned to 12 four-person groups. Subjects in Part Two were 18 students. Results of posttests in Part One showed that the order from best to worst conditions, averaged over ability levels, was: mixed-ability grouping, individual learning, and uniform-ability grouping. Examination of group process showed that in mixed-ability groups, high ability-students explained to less-able members; when in uniform-ability groups, however, highs rarely explained. Those who actively explained showed excellent delayed performance; those who did not explain showed poor delayed performance. Thus, the effect of the learning setting depends on the ability of the student, the ability of the student relative to that of teammates, and the role the student plays in the group. Educational research should closely examine the relation of group process and student characteristics. (Author)

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LEARNING IN INDIVIDUAL AND SMALL GROUP SETTINGS

NOREEN M. WEBB

TECHNICAL REPORT NO. 7
APTITUDE RESEARCH PROJECT
SCHOOL OF EDUCATION
STANFORD UNIVERSITY

Sponsored by

Personnel and Training Research Programs
Psychological Sciences Division
Office of Naval Research

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The present study compared learning in individual and small group settings, accounting for differences between conditions as partly a function of student ability and group process. The following questions were examined: (1) How does the individual's achievement when learning in a group differ from that student's achievement when learning alone? (2) How do ability level of a group and the range of ability in the group influence learning? (3) What aspects of group interaction account for any difference between an individual's learning in a group and learning when alone?

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The study had two parts. Part I provided a comparison of learning in individual and group settings. Students in Part I learned how to solve three kinds of mathematical problems, the first in an individual setting and the remaining kinds in group settings. Data on the last two tasks yielded reliability information on learning in group settings. Students in Part II performed two tasks, both in individual settings. Posttest scores yielded reliability information on learning in individual settings. Each task was learned in a three-phase session; sessions were spaced one week apart. During problem-practice, students learned how to solve complex problems which incorporated those components. During testing, students were tested individually on complex problems similar to those solved during problem-practice and a delayed test a week later. Problem-practice distinguished individual and group conditions. In Part I, eleventh-grade students of average and superior ability were assigned to twelve four-person groups. Three strata of comparative ability were defined: those in the lowest stratum had IQs near 100. Each of the six mixed-ability groups had one high-ability, two medium-ability, and one lower-ability student. In a uniform-ability group, all students came from the same ability stratum. There were two uniform-ability groups at each ability level. Half of the groups were all female; half were all male. Eighteen students participated in Part II.

Results of the posttests in Part I showed that the order from best to worst conditions, averaged over ability levels, was: mixed-ability grouping, individual learning, and uniform-ability grouping. This order held for lower-ability students. High-ability students performed equally well after learning individually or in mixed-ability groups; they performed less well in uniform-ability groups. The order from best to worst conditions for medium-ability students was: uniform-ability grouping, individual learning, and mixed-ability grouping.

Examination of group process showed that in mixed-ability groups, high ability-students explained to less-able members; when in uniform-ability groups, however, highs rarely explained. Those who actively explained showed excellent delayed performance; those who did not explain showed poor delayed performance. Lower-ability students in mixed-ability groups were often targets of explanations. Lows who received explanations from more-able members did better than lows who did not. In uniform-low-ability groups, students did not benefit from explanations because they were unclear and often incorrect. Those medium-ability students who actively interacted in solving problems benefited from group learning. In uniform-ability groups, all members actively participated, and they performed very well on most tests. In mixed-ability groups, those medium-ability members who did not actively teach or aggressively ask for explanations were ignored; they performed worse than after individual learning. Those who actively explained did well on all tests; those who received explanations did less well, but better than after individual learning.

Thus, the effect of the learning setting depends on the ability of the student, the ability of the student relative to that of teammates, and the role the student plays in the group. Educational research should closely examine the relation of group process and student characteristics, including ability and personality variables, to learning outcomes in group settings. Longitudinal studies of small groups are needed to determine the stability of group process over time.

PREFACE

The investigation reported herein is part of an ongoing research project aimed at understanding the nature and importance of individual differences in aptitude for learning. Information regarding this project and requests for copies of this or other technical reports should be addressed to:

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Noreen M. Webb October 1977

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CHAPTER I

THE PROBLEM: A REVIEW OF RESEARCH

Introduction

The students in a classroom do not learn alone, as subjects in the laboratory usually do. Some part of a student's time is spent in interacting groups; and fellow members influence the student even when all students are working at their own seats. What each student learns will be affected by other members of the group, and by the group setting. The instructional outcome for the individual student presumably depends on the characteristics of the group itself and on the student's experience within that group.

In the usual interpretation of educational experiments (and in the statistical tests made), the learner is assumed to be isolated from other students. Little research has focused on the effects of the group environment on the individual learner. Nor, as Gurnee (1968) noted, has the topic received much thought.

> An examination of textbooks in educational psychology published since 1950 indicates extremely few with any references to social stimulus conditions of learning. Where group behavior is discussed, it is almost invariably in other than a learning context. During the height of the group-dynamics movement there was some interest in its applicability to education, but this interest pertained to problem-solving and creative behavior rather than to learning processes. In spite of the fundamental importance of learning in the educational process, there seems to be little interest in exploring social environments which might facilitate that learning. (p. 33)

Gurnee was concerned mainly with the possibilities of collaborative learning, but his comments apply in general to the impact of groups on learning.

Theorists and methodologists have begun to reconsider learning as partly a function of the characteristics of the group in which the learner is situated. Instructional treatments in intact groups may influence learning: Cronbach (1976) suggests (1) The effect of the treatment depends upon characteristics of the individual learner, independent of the characteristics of other members of the group. (2) The effect of the treatment depends upon the mean level of certain group characteristics. (e.g., The treatment may work better in a group with high mean ability than in one with low mean ability. All members in the former group would benefit regardless of their relative standing with that group.) (3) The third kind of effect is comparative within the group (individual-within-group). The effect of the treatment depends upon how the characteristics of the individual compare with the group average.

Even the literature on learning in group settings typically reports whether group settings or individual settings produce superior learning overall, rarely considering the characteristics of the individual and the group.

Communication in an interacting group can certainly influence each member's learning. Virtually no study in the literature, however, examines group processes affecting learning in interacting groups. The present study makes a start toward comparing learning in interacting groups with learning by individuals singly. It attempts to explain differences as a function of the characteristics of the individual and the group, and group process.

Defining a "Group"

A collection of persons in an elevator is not a group. But there is little agreement among psychologists and sociologists on what distinguishes such a collection of individuals from a group.

Steiner (1972) raised several questions regarding the definition of group:

> How intense, direct, and persistent must the responsiveness of the members be in order for a collection of individuals to qualify as a group? When the members go their separate ways after a period of interpersonal activity, does the group cease to exist? Is it a new group when members resume their collective actions? By what criteria can one specify who belongs in the group and who does not? Do groups possess attributes that entitle them to be regarded as entities in the sense that separate individuals are deemed to be? Or is it true, as some writers have contended, that groups have no reality apart from that of their individual members, the word "group" being only a convenient label for a class of people who are most accurately viewed as separate and distinct behavioral agents? (pp. 5-6)

Setting these questions aside, Steiner defined groups as "small sets of people who influence one another through direct, generally face-to-face, contacts" (p. 6).

In a review of early experimental studies of the effects of groups, McGrath (1964) noted that "In these early studies, the 'group' variable being studied was the mere presence and activity of other people, not any direct interaction among those people" (p. 63). Even a decade ago, some psychologists did not include interaction as a requirement of a group.

Mills (1967) defined groups as "units composed of two or more persons who come into contact for a purpose and who consider the contact meaningful" (p. 2). More recently, Hare (1976) insisted that

> For a collection of individuals to be considered a group there must be some *interaction*. In addition to the interaction of the members, four features of group life typically emerge as a *collection of individuals* develops into a *group*: . . . the members of a group share a common *goal* and set of *norms*, which give direction and limits to their activity. They also develop a set of *roles* and a *network of interpersonal attraction*, which serve to differentiate them from other groups. (pp. 4-5)

In the present study, a group consisted of four previously unacquainted students who were brought together to learn scholastic tasks. Group members had contact with one another for several hours once a week for four weeks. During this time, specific roles developed within a group which related to achievement by each student. The collections of individuals in the present study, then, satisfied the major requirements of Hare's "groups."

Relevant Research

It has been asserted[1] that the context in which students learn will influence their motivation and learning (e.g., Hilgard, Sait, & Magaret, 1940; Sears, 1940; Deutsch, 1951; Perkins, 1951; Withall, 1951; Coleman, 1966; Meyer, 1970; Lindgren, 1972; Anderson & Walberg, 1974). But little research has examined *how* the context influences learning, i.e., how input, described by the characteristics of the individual and of his learning environment is transformed into output.

A large body of literature compares individual and group performance on isolated tasks (Watson, 1928; Shaw, 1932; Timmons, 1942; Taylor & Faust, 1952; Moore & Anderson, 1954; Lorge, Tuckman, Aikman, Spiegel, & Moss, 1955; Marquart, 1955; Yuker, 1955; Lorge & Solomon, 1959, 1960; Goldman, 1965; Johnson & Torcivia, 1967). These studies contrast the work output of groups with the pooled output of individuals working alone. Only a small portion of this literature reports on learning per se (Perlmutter & deMontmollin, 1952; Hoppe, 1962; Beaty & Shaw, 1965; Laughlin, McGlynn,

---

[1] Not without controversy (Hauser, 1970, 1971).

Anderson, & Jacobson, 1968). And scarce indeed are studies that compare learning by a student alone with learning by the student within a group.

Individual Learning versus Learning in Groups

Gurnee (1937, 1939, 1962) reported experiments on maze learning. In his group condition, no verbal interaction was permitted. Each group member made a choice at each step orally. Members responded simultaneously; the group "response" was the majority vote. Gurnee compared the performance of persons who learned in groups with that of others who learned alone. Gurnee's group condition arranged for guided individual learning, guidance coming from the responses of other members of the group.

In Gurnee's first study, the subject performed a seventh trial alone after six trials in the individual or group condition. No difference between conditions appeared. In the second study, subjects who had six trials in the group condition made fewer errors on the seventh trial (on the average) than subjects who had six trials in the individual condition.

In a 1962 study, Gurnee recorded the responses of subjects during the trials in the group condition. These subjects made fewer errors during practice trials than did subjects learning alone, and the variability of responses among group members was less than among solitary learners. Gurnee suggested that able subjects react quickly with the right answer and consequently provide prompts and reinforcements for doubtful and less able members. Some subjects agreed that they had learned by imitating other members' responses. Gurnee's findings suggest that being in a group enhances individual learning. He did not, however, study interacting groups, nor complex learning tasks.

Hudgins (1960) compared problem solving by subjects in groups and in independent work. During the first phase of the experiment, half of the subjects solved arithmetic problems in groups and half solved problems alone. Each group was told to arrive at a collective answer to each problem, but group members were not given instructions to work together to solve the problems. During the second phase, subjects worked individually. In the first phase, groups solved more problems than individuals. In the second phase, however, the mean score of subjects who had worked in groups initially equalled that of subjects who had worked alone initially. Hudgins concluded that "group experience does not enhance individual problem solving" (p. 42).

Hudgins observed two patterns of interaction in groups. In the first pattern, one member solved a problem and communicated the answer to the others. In the second pattern, the members solved the same problem individually and then compared and evaluated answers. Hudgins did not indicate which pattern produced higher scores. His subjects did not interact to solve a problem. With no such interaction, Hudgins' group condition approximated individual learning.

Klausmeier, Wiersma, and Harris (1963) examined the transfer of concept attainment by subjects who had initially learned alone. In the initial learning situation, subjects learned concepts as individuals, in pairs, or in quads. Subjects in groups were instructed to discuss the problem and to permit any group member to offer solutions. Subsequently, subjects learned a transfer concept as individuals. Half of the subjects worked on the transfer concept immediately after initial learning; half began work after a delay of twelve minutes.

In initial learning, pairs and quads attained concepts faster than individuals. On the transfer task, however, subjects who had learned initially as individuals were more efficient than those who had learned initially in pairs or in quads. The differences were statistically significant for immediate transfer. Klausmeier et al. (1963) suggested the following explanation for the crossover in efficiency of individuals and groups:

> In the initial learning situation, the pairs and quads secured a large amount of information in a relatively short period of time, analyzed the information correctly, recalled the information, and deduced the correct concepts. Pairs and quads accomplished this better collectively than did individuals working alone; however, not all members of the pairs and quads learned well. . . . Working alone initially, the individuals often guessed incorrectly what the concept was without having complete information, or did not analyze the information correctly, or did not recall it well. However, each individual was active and most of them improved performance across concepts during the initial learning and also learned how to go about the task. (p. 164)

Klausmeier et al. did not describe group process to support this explanation.

Lott and Lott (1966) related learning by individuals in groups to group cohesiveness and IQ. Fourth- and fifth-grade students learned simple Spanish vocabulary. High-cohesive and low-cohesive groups were formed on the basis of ratings of mutual liking. All groups were of uniform ability: high-IQ or low-IQ. Within all groups members were of the same sex.

Lott and Lott examined students' performance on learning trials, a retention test, and relearning trials. Subjects in high-cohesive, high-IQ groups learned better than students in low-cohesive, low-IQ groups. Contrary to the authors' expectation, low cohesion was associated with success among low-IQ groups. Even more surprising, students in low-IQ groups outperformed students in high-IQ groups (though not by a statistically significant amount).

Lott and Lott discussed their results in terms of drive level and task complexity. They hypothesized that cohesiveness and task complexity are positively related to drive level. They assumed that the task is relatively simple for high-IQ subjects, and consequently members' drive level is low. When drive level increases in high-cohesive groups, performance improves. For low-IQ subjects, the same task is relatively complex. Participating in a high-cohesive group raises the drive level of members beyond their optimal level for learning that task, and consequently performance suffers. The authors did not support their hypothesis with direct measures of drive level. Nor did they examine group process to understand why cohesiveness interacted with IQ.

Lemke, Randle, and Robertshaw (1969) examined concept attainment by individuals alone or in uniform-high-or uniform-low-ability groups. The investigators did not report whether group members interacted while learning. Persons trained alone performed better on an individual transfer task than persons trained in groups. Lemke et al. hyopthesized that some subjects depend on the best subjects in the group instead of learning the concepts. Neither variability of responses nor verbal reports of subjects were discussed.

Lemke and Hecht (1971) and Beane and Lemke (1971) examined the transfer of concept attainment in interacting groups. Lemke and Hecht examined pairs of subjects with high or low pretest scores. When subjects were trained on relatively few concepts, training in pairs enhanced transfer performance of low-ability subjects. Beane and Lemke included homogeneous and heterogeneous pairs and quads, and confirmed and extended the results of Lemke and Hecht. Low-ability subjects trained in homogeneous pairs performed better on transfer tasks than low-ability subjects trained alone. Low-ability subjects trained in homogeneous quads did better on the transfer task than low-ability subjects trained in homogeneous pairs. The results were just the opposite among high-ability subjects.

Beane and Lemke offered the following explanation of their results and the results of Lemke and Hecht:

> From the previously cited effects of intelligence we can infer that when low-ability subjects come to a training task, the probability is reasonably low that either will quickly develop a systematic individual strategy. Thus, they cooperatively design a group strategy which can be modified in the individual performance of the transfer setting--proactive facilitation occurs. The more low-ability subjects in the group, the more information is processed, the greater the facilitation.
>
> When four high-ability subjects attempt to train as homogeneous quads, the probability is higher that each subject will quickly develop an individual strategy. Group interaction forces the subject to adopt an alternative group strategy because high-ability subjects each develop and bring a different individual strategy to the setting. A great deal of interference occurs as subjects impose and/or develop a group strategy. When the high-ability subject again finds himself in the individual transfer setting he requires the old individual strategy or a variant thereof. As the high-ability subject attempts to develop an individual strategy, retroactive inhibition occurs. (p. 217)

This explanation could not be confirmed because the investigators did not examine group process.

Amaria, Biran, and Leith (1969) investigated the effects of grouping with wide or narrow range of ability in the group. Five experiments were conducted, one in each of five schools. In all, 385 students participated. Students of ages 10 to 12 studied a programmed unit on levers in science class. The authors compared mixed-ability pairs, uniform-ability pairs, and individual learners. In any pair, both members were of the same sex. A mixed-ability pair had a student of above-average IQ and a student of below-average IQ. Uniform-ability pairs had two members of above-average ability, or two of below-average ability.

At the end of the three-part program, each student was given a posttest; later he took a delayed transfer test. Among lower ability students especially, cooperative learning seemed in general to be better than individual learning. High-ability students also did better when learning in groups, which is contrary to the finding of Lemke and Hecht, (1971).

The results of mixed-ability and uniform-ability pairing were not entirely consistent, but suggested that mixing abilities was better than pairing students of the same ability. Sex and ability interacted with method of pairing in the results of the posttest in one school, and in the results of the transfer test in another school. Girls learned better in mixed ability pairs, whereas boys learned better in same-ability pairs. In all schools, less-able students learned better in mixed-ability pairs. Ability of the partner did not generally affect learning of the more-able students.

Amaria et al. offered an explanation for the better learning in mixed-ability pairs than in same-ability pairs, though they did not explain why learning in groups was superior to learning alone. They hypothesized that a "teacher-learner" relationship develops in a mixed-ability pair: "Less bright children are probably often inadequate to cope with the conceptual structures presented without careful rehearsal and practice. Hence, if an intelligent child is obliged to spend time in organizing the concepts and operations, explicitly, for a less intelligent child both will tend to profit from the experience" (p. 102). In their study, the learner (less-able student) profited more than the teacher (more-able student).

The authors observed that in some pairs, leaders and followers developed; in other pairs, members cooperated equally. Amaria et al. (1969) did not closely examine group process, and so did not explain why learning in some groups was better than in others, or why learning in groups was superior to learning alone. But the design of their study is more comprehensive than any other study of individual and group learning reported to date.

The research considered above suggested how group experience may influence learning by an individual. But no study examined group process in a systematic way. A recent study by Hackman and Morris (1975) appeared to be the first to examine input-process-performance relations. Hackman and Morris investigated problem-solving rather than learning. Effectiveness of the group as a team was the focus. The authors identified and scored sixteen categories of task-related interaction among group members. Measured characteristics of written group products served as outcomes. No consistent results were obtained. Nonetheless, the Hackman-Morris procedures are relevant to individual performance and possibly to individual learning.

Table 1 summarizes the design and results of each study that compared learning by subjects in groups with that by subjects alone. The results of the studies are not consistent. The group experience enhanced learning in some studies, but was detrimental to learning in other studies. Some studies showed no difference between learning in groups and alone. This result occurred most often in groups in which interaction among group members was minimal.

Learning in the Classroom: Group and Individual Procedures

Teachers and researchers have compared group and individual methods of teaching in hundreds of schools over the past half century, with mixed results. Most studies compared achievement of students taught by lecture methods with achievement of those taught by discussion methods. Another large body of research compared programmed instruction with conventional teaching. Few, however, compared programmed instruction with learning in interacting groups.

In most of the educational studies comparing group and individual instruction, the individual method allowed social interaction among students. One study, however, compared students learning in traditional classrooms and students learning on their own but with occasional consultation with the instructor. Ryan (1932) divided English and education classes into halves matched on ability. One half of each class studied as individuals, the other half attended conventional classes. After six weeks, the half-classes switched conditions. During the final six weeks, all students attended the regular class. On achievement tests given at the end of each six week period, students who attended class did better than students who had worked individually.

H. C. Smith (1955) compared the lecture-discussion method and teamwork in introductory college psychology. Students in five small teams worked on group projects for a semester. Every student in the teams and in the lecture-discussion class was given an achievement test at the beginning and at the end of the semester. Students in teams tended to show greater achievement gains over the semester than students in the lecture class, but the result was not statistically significant.

Table 1

Summary of Design and Results of Studies Reviewed

Investigator	Group Size	N Groups	N Individ.	Composition Rule	Interaction	Subject Matter	Results[1]
Gurnee (1937)	10	12	42	none	not allowed	maze learning	no difference
Gurnee (1939)	9-14	not reported	42	none	not allowed	maze learning	GC advantageous
Gurnee (1962)	50	1	50	none	not allowed	maze learning	GC advantageous
Hudgins (1960)	4	16	64	homogen. ability	allowed (but min.)	arithmetic problems	no difference
Klausmeier, Wiersma, & Harris (1963)	2- 4	32	32	none	encouraged	concept attainment	IC advantageous
Lott & Lott (1969)	3- 4	62	none	homogen. ability (high/low) x homogen. cohesive. (high/low)	allowed (but min.)	Spanish vocabulary	high IQ:high cohesive advantageous low IQ: low cohesive advantageous
Lemke, Randle, & Robertshaw (1969)	2 4	24 24	48	homogen. ability (high/low)	not reported	concept attainment	IC advantageous
Lemke & Hecht (1971)	2	64	64	homogen. ability (high/low)	encouraged	concept attainment	low ability: GC advantageous
Beane & Lemke (1971)	2 4	16 8	16 8	homogen. ability (high/low) heterogen. ability (1 high and 1 low or 2 high and 2 low)	encouraged	concept attainment	low ability: GC advantageous high ability: IC advantageous
Amaria, Biran, & Leith (1969)	2	129	129	homogen. ability (high/low) heterogen. ability (1 high and 1 low)	encouraged	levers	GC advantageous

---

[1] GC = group condition, IC = individual condition.

Spence (1928) compared lecture and discussion methods of instruction. During the first semester, one class attended lectures while another class participated in class discussions. During the second semester, the methods of instruction were reversed. Examinations given at the end of each semester indicated that students learned more under the lecture system. Barton (1926), using first year algebra classes and Thie (1925), using high school English classes, compared instruction by lecture and small group discussions. Both investigators found the discussion method superior. Zeleny (1927) and Haigh (1956), investigating learning in psychology and sociology, respectively, found no difference between achievement scores in lecture classes and in discussion classes.

Dubin and Taveggia (1968) reviewed four decades of studies comparing lecture and discussion methods. Of 88 independent comparisons reported in the studies they reviewed, 45 found the lecture method superior and 43 found the discussion method superior.

The studies reviewed above and those reviewed by Dubin and Taveggia offer contradictory results. But the studies may not have had comparable teaching procedures. The "lecture" and "discussion" labels are not well-defined; few investigators explicitly described the teaching methods used. Finally, few of those investigators described the group processes that may help to explain why one method of instruction produced greater achievement than another.

Cross-Age and Peer Tutoring

A large body of educational research has examined achievement in tutorial situations. The one-on-one tutorial can be seen as a two-person small group in which group members are assigned specific roles in advance. Most studies investigated pairs in which the tutor was older than the tutee. Regardless of the difference in age, most studies showed that both members of the pair seemed to benefit from the interaction.

Cloward (1967) investigated reading achievement of more than 300 fourth- and fifth-grade students tutored by tenth- and eleventh-grade students. Tutoring took place outside of school hours. Students who received four hours of tutoring per week performed significantly better on standardized reading achievement tests than students from the same schools who received no extra instruction. The tutors also showed significantly greater reading improvement than students from the same schools who did not participate in the program. The benefits to tutors and tutees may have resulted from the exposure to additional instruction, rather than interaction between students.

In the study of Lippitt and Lippitt (1968), seventh- and eighth-grade students tutored fourth-, fifth-, and sixth-grade students in reading, arithmetic, and language. Students in six schools participated in the three-year program. Tutoring took place during school hours when control students received conventional instruction. Both tutors and tutees made greater academic gains than control students.

Klosterman (1970) investigated reading achievement among fourth-grade students tutored by students majoring in elementary education. Most students participated in one-on-one tutorials. Some tutors taught small groups of students. (The size of the groups was not reported.) All tutees did significantly better on tests of vocabulary and reading comprehension than students who received regular classroom instruction. Students tutored individually did no better than those tutored in small groups.

Devin-Sheehan, Feldman, and Allen (1976) reviewed over a decade of studies on cross-age tutorials. Studies used from 300 to 1,000 students in programs lasting from six months to three years. In most studies, tutors taught younger students who were below grade level in reading achievement. Nearly every study reported that the tutorial was beneficial to tutor and tutee. In many of these studies, tutors made greater gains than tutees.

Some studies investigated tutoring among peers. In the study of Mollod (1970), more-able second- and third-grade students tutored less-able classmates. Control students were taught vocabulary for two and one-half hours per week and reading comprehension for four hours. Students in tutorials spent half of that time in class and half in tutorial. After four months, tutors and tutees outperformed control students significantly. Tutors improved more than tutees. In the study of C. C. Smith (1977), high-ability students tutored low-ability students, and average-ability students tutored average-ability students in mathematics classes. At all levels of ability, students who had participated in tutorials performed better on achievement tests than control students of comparable ability who received additional conventional instruction instead of tutoring.

The evidence is clearly in favor of tutorials as a supplement to, or partially replacing, conventional instruction. In nearly every comparison with control students, tutors and tutees showed marked improvement. In most studies, tutors improved more than tutees.

After examining anecdotal descriptions in reports by evaluators, tutors, program supervisors, parents, and tutees, Gartner, Kohler, and Riessman (1971) proposed the following mechanism to explain how a tutor learns by teaching another child:

> He reviews the material; he has to organize, prepare, illustrate the material to present it to his student; he may try to reshape or reformulate it so as to enable his pupil to learn it and thus himself sees it in new ways; he may need to seek out the basic character of the subject, its structure, in order to teach it better, and may thereby himself understand it better. (p. 62)

This explanation is tentative. No investigator systematically examined the interaction between tutor and tutee to explain why the tutor benefited. Most investigators labeled the tutor as "teacher" but did not describe how tutors taught. Nor did any investigator systematically examine how or what control students learned.

The Present Research Problem

Learning in interacting groups is still unexplored territory. The few studies comparing learning by subjects in interacting groups with that by subjects alone produced inconsistent results. No investigator closely examined group process to explain the results of his study. This study attempts to investigate group process systematically, not only to relate group characteristics to member learning, but also to show how learning by individuals in interacting groups differs from learning by individuals alone. The questions motivating this study are as follows:

1. How does the individual's achievement when learning in a group differ from that student's achievement when learning alone?
2. How do ability level of a group and the range of ability in a group influence learning?
3. What aspects of group interaction account for any difference between an individual's learning in a group and learning when alone?

Each of the ten studies reviewed varied or controlled one or more of the following variables: instructions for interaction among group members, composition rule of the group, and subject matter. In four studies, interaction among group members was encouraged (Klausmeier et al., 1963; Amaria et al., 1969; Lemke & Hecht, 1971; Beane & Lemke, 1971). Three of the four studies encouraging interaction recognized ability as an important characteristic of the group (Amaria et al., Lemke & Hecht, Beane & Lemke). Two studies examined the range of ability in a group as well as average ability in a group (Amaria et al., Beane & Lemke). These two studies compared homogeneous and heterogeneous groups with high or low mean ability. Only one study used a task that might be learned in the classroom: a unit on levers (Amaria et al.). Even that task mainly required memorization.

The present study includes all variables manipulated or controlled in the studies reviewed. First, interaction among group members was encouraged by means of detailed instructions. Second, groups were formed on the basis of ability--high, medium, and low. Third, the range of ability in a group was manipulated. Some groups had a narrow range of ability; some had a wide range of ability. As in four of the studies reviewed, homogeneous groups with high or low mean ability were formed. Unlike any past work, the present study examined homogeneous groups with medium ability. Fourth, the learning task was of complexity appropriate for the classroom. Students learned how to carry out a mathematical analysis. The problems required basic algebra skills, yet were novel for the student.

The literature on group size was examined to determine the optimal group size for learning. Hare (1962) concluded, in a review of small group research, that "The pair and the three-person group have special characteristics of intimacy and of power structure" (p. 225). Thus, dyads and triads are special cases of small groups. Slater (1958) found that subjects enjoyed participating in groups of four to six members more than in smaller or larger groups:

> The disadvantages of larger groups match those found by earlier studies, and are readily verbalized by the subject. Group members are seen as too aggressive, impulsive, competitive, and inconsiderate, and the groups as too hierarchical, centralized, and disorganized.
>
> The disadvantages of the smaller groups are not verbalized by members, but can only be inferred from their behavior. It appears that group members are too tense, passive, tactful, and constrained

> to work together in a manner which is altogether satisfying to them. Their fear of alienating one another seems to prevent them from expressing their ideas freely. (p. 138)

Carter, Haythorn, Meirowitz, and Lanzetta (1951) observed individual participation in groups of varying sizes. They concluded that groups of size four gave individuals freedom to participate, without members feeling threatened or inhibited about participating. In groups of size larger than four, members complained that one or two members dominated interaction, making it difficult for others to participate freely. In light of these observations, a group size of four was chosen for this study.

Sex within a group was controlled. The studies reviewed above typically ignored sex as a grouping variable. But there is evidence from many studies (e.g., Hoffman & Maier, 1961) that in mixed groups male members tend to dominate group activity in instructional problem-solving tasks. In this study, therefore, only single-sex groups were used. There were six male groups and six female groups.

Few of the studies reviewed above used a repeated measures design. In the present study, all students learned one task in an individual setting and two tasks in a group setting.

The present study, then, compares learning by students in interacting small groups with that by students alone. The design manipulated or controlled the major variables examined in the small-group literature on learning: instructions for interaction among group members, ability composition rule of the group, subject matter, and group size. In the present study, group members were encouraged to help each other learn how to solve mathematical reasoning problems, in four-person groups with uniform high, medium, or low ability, or in groups with mixed ability. Group process was examined to show how learning by individuals in interacting groups differs from learning by individuals alone.

CHAPTER II

DESIGN AND PROCEDURE

Overview of the Design

The basic unit in the design was the task performed by the students. There were three tasks. In each, the student was to carry out a mathematical analysis. There were three phases of work on a task: training, problem-practice, and testing. During the training phase, students received instruction on the components of the task. During the problem-practice phase, students used the component concepts and skills to solve complex problems. Later, students were tested on complex problems similar to those solved during problem-practice.

The phase of the task that distinguished the individual and group conditions was problem-practice. On one task, every student solved these problems individually. On tasks assigned to the other condition, members of a group worked together to solve each problem in turn. On all tasks, students worked individually during the training and testing phases.

Students participating in Part I of the study performed three tasks, the first task in the individual condition, the other two in the group condition. This provided a comparison of work in group and individual settings. One task was assigned for each session; successive sessions for a student were spaced one week apart. Figure 1 shows the schedule for each student in Part I. All students in Part I performed Task A in the first session, Task B in the second session, and Task C in the third session. The data on Tasks B and C yielded reliability information on individual differences in group learning.

The students in Part I were organized into groups of four who went through the three conditions as a unit. Half of the groups were all female; half were all male. Some groups were of mixed ability; the rest were homogeneous groups of high, medium, or low ability.

Part II was designed to obtain information on reliability of individual differences in learning in individual settings. A fresh set of students performed Tasks A and B in the individual condition. Figure 2 shows the schedule for each student in Part II.

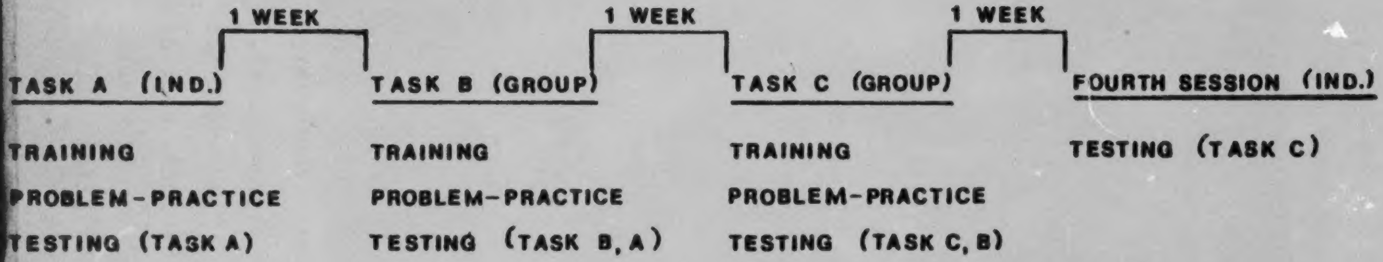
1 WEEK
1 WEEK
1 WEEK
TASK A (IND.)
TASK B (GROUP)
TASK C (GROUP)
FOURTH SESSION (IND.)
TRAINING
PROBLEM-PRACTICE
TESTING (TASK A)
TRAINING
PROBLEM-PRACTICE
TESTING (TASK B, A)
TRAINING
PROBLEM-PRACTICE
TESTING (TASK C, B)
TESTING (TASK C)

Figure 1. Schedule for students in Part I.

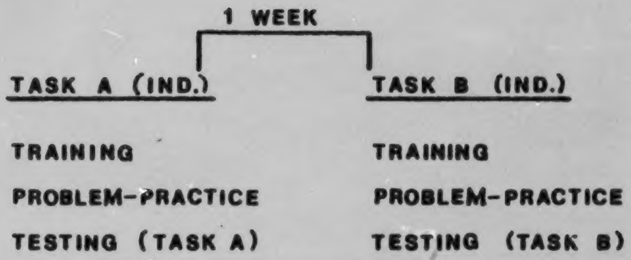
1 WEEK
TASK A (IND.)
TASK B (IND.)
TRAINING
PROBLEM-PRACTICE
TESTING (TASK A)
TRAINING
PROBLEM-PRACTICE
TESTING (TASK B)

Figure 2. Schedule for students in Part II.

Subjects

The subjects were selected from a pool of 241 students from three high schools in Palo Alto, California. The 241 students had responded to a notice inviting students to participate as subjects in a three-year project on learning at Stanford University. Members of the pool took various tests and participated in several studies. The present study occurred about 18 months after the start of the program of studies. At the time of the present study, three students were in tenth grade, 181 were in eleventh grade, 54 were in twelfth grade, and three had graduated from high school the previous June. A pilot experiment showed that eleventh- and twelfth-grade students had the necessary skills to learn the tasks. Twelfth-graders, however, had covered much of the subject matter in school; eleventh-graders had not. Thus, only eleventh-graders were considered in the present study. Most of the subjects selected had participated in prior experiments of the project. None of the prior experiments was closely related to the tasks of the present study.

Aptitude and achievement tests previously given were used in the selection of subjects in the present study; they are described next. The tests at hand covered a wide range of abilities: verbal, spatial, and quantitative abilities. To supplement these scores, students' scores on the California Test of Basic Skills were obtained from the schools. A factor analysis was performed using all scores in the test battery. Two orthogonal general ability factors emerged: scholastic ability (G_c) and nonverbal spatial-analytic ability (G_f). The first factor was a general educational-achievement or scholastic-ability factor. It included tasks requiring the student to remember or apply verbal knowledge: vocabulary (generating definitions of words, synonyms, antonyms, verbal analogies), comprehension, information, and school achievement tests. The second factor was a nonverbal spatial-analytic ability factor. It included spatial tests, hidden figures tests, tests of mathematical reasoning, and figural matrices. See Snow et al. (1977) for a more complete description of the ability factors.

The bivariate distribution of scores on the two factors was divided approximately as seen in Figure 3. The broken curve indicates the boundary of scores of the 181 eleventh-grade students available for the study. The solid curve indicates the boundary of scores of the students who were

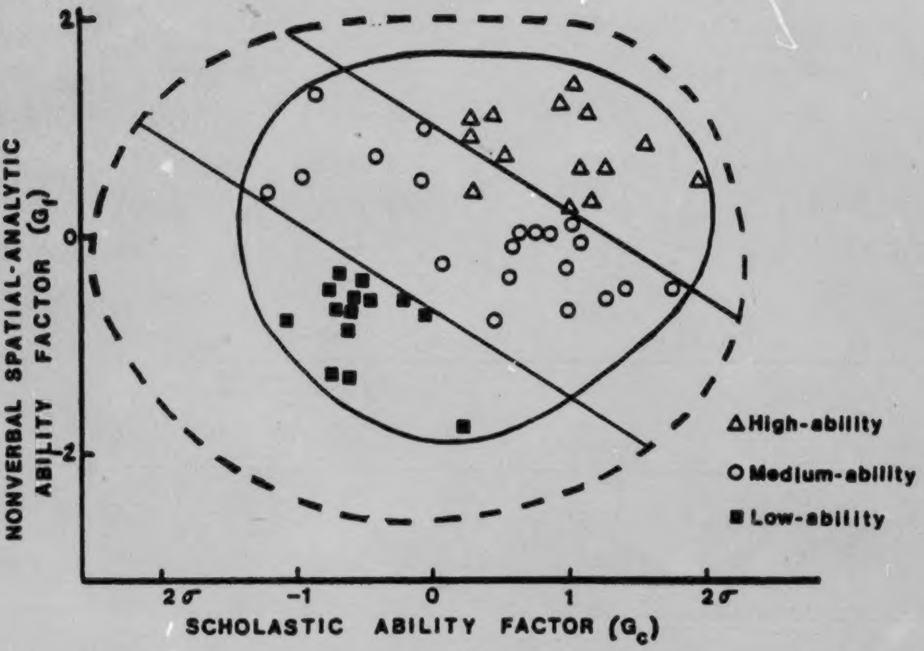

Figure 3. Bivariate distribution of student pool and of students selected for Part I.

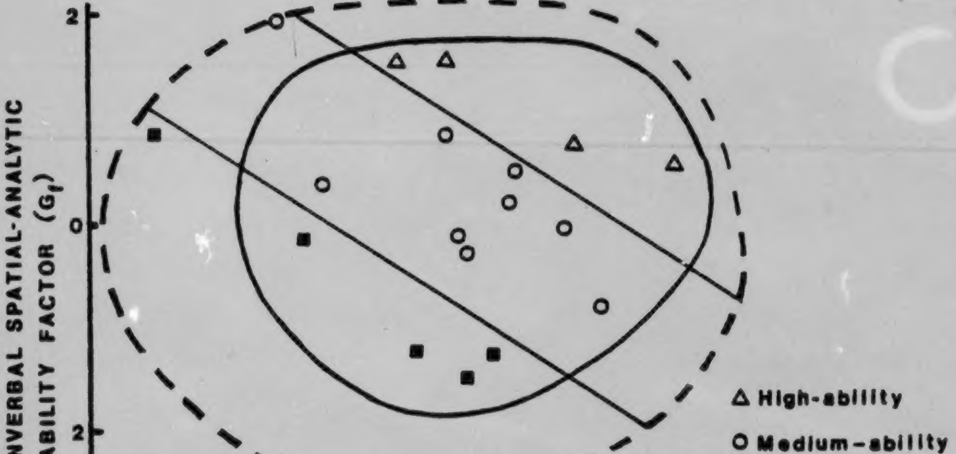

Figure 4. Bivariate distribution of student pool and of students selected for Part II.

considered for selection. Subjects were selected who had somewhat consistent standings on the two ability factors; students who were very high on one factor and very low on the other were ruled out.[1] The high-ability region contains about 23 percent of the 181 students available for selection in the study. The medium-ability region contains about 47 percent. The low-ability region contains about 30 percent of the students. The distributions of male and female subjects were not identical. As a result, one high-ability male had G_f and G_c scores within the range of medium-ability females.

For Part I of the study, 48 students were needed: 14 of high ability, 20 of medium ability, and 14 of low ability. Students identified as eligible were contacted by telephone to determine whether they were willing to participate, and to establish schedules of free time. Students were told that there would be four sessions, one week between each session, and that subjects would be paid about $2.50 per hour. Students were divided into clusters according to ability and the times they were available. Within the clusters groups of four were formed. In the uniform-ability condition, four students from one region (high, medium, or low ability) were assigned to a group. In the mixed-ability condition, two students from the medium-ability region, one student from the high-ability region, and one student from the low-ability region formed a group. Table 2 shows the factor scores of students in each group.

Close friends were not assigned to the same group. Whenever possible all three high schools were represented in a group. When it was necessary to assign several students attending the same school to a group, it was determined that they were no more than casual acquaintances.

For Part II of the study, 18 students were selected according to ability and availability. The criterion of consistent scores on the ability factors was relaxed somewhat for the selection of students in Part II. Five high-ability students, nine medium-ability students, and four low-ability students participated in Part II. Figure 4 represents scores of the subjects selected for Part II. As in Figure 3, the broken curve indicates the range of students in the pool, and the solid curve surrounds scores of students selected for Part I.

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[1] Students who were very low on both factors were considered for selection, but did not have time to participate.

Table 2

Factor Scores of Students in Groups for Part I

		Factor Scores of							
Group Composition	Factor	Females				Males			
Uniform high ability	G_f	1.3	.3	.8	.4	.9	1.0	.1	1.7
	G_c	.9	1.2	.3	.8	1.2	.7	.4	.6
Uniform medium ability	G_f	- .1	- .0	.8	.7	.6	1.0	.9	- .2
	G_c	1.1	- .2	.2	- .7	.1	- .4	.0	.6
Uniform low ability	G_f	- .8	- .6	-1.1	- .8	- .2	- .6	- .7	- .3
	G_c	- .3	- .5	- .6	- .4	- .6	- .4	- .6	- .4
Mixed ability	G_f	1.2	- .5	- .7	1.0	.5	.1	- .6	.8
	G_c	- .4	.8	- .8	.4	.0	1.0	- .5	- .2
Mixed ability	G_f	.4	.7	- .8	-1.3	.4	.5	.8	.0
	G_c	.0	1.3	-1.2	.4	- .3	.2	1.5	-1.7
Mixed ability	G_f	.8	1.5	- .7	-1.1	.1	- .8	- .9	.3
	G_c	.7	- .4	- .6	.6	.9	-1.2	1.2	- .7

For Parts I and II of the study pooled, the mean IQ on the Wechsler Adult Intelligence Scale for high ability students was 124. The mean IQ for medium ability students was 117. The mean IQ for low ability students was 105.

Materials

Task Types

Task A was based on mathematical probability. Each student received instruction on calculating the expected value of a game of chance. Task B dealt with polygonal numbers. The students were taught to derive a mathematical formula for the nth polygonal number, the total number of dots in a particular geometric array of dots. Task C involved negative number bases. Each student was given instruction on converting numbers presented in different positive and negative number bases so as to find their sum.

Each task was constructed to have four separate components. Mastery of all components was necessary in performing the task. During the training phase, students were to learn the components and during problem-practice to put the components together as required in problems. This made it possible to compare the effect of the individual and group settings on learning in the latter phase. Building the same number of components into each task made scoring across tasks somewhat comparable.

Training Materials

At the beginning of each session, all students were given individual instruction booklets on the task for that session. The training booklet was divided into four lessons, each lesson concentrating on one component of the task. The four lessons of a training booklet were similar in length and difficulty. Each lesson consisted of one or two pages of text presenting definitions, descriptions, sample exercises and solutions. The text for each lesson was followed by several exercises for the student to do.

The training booklet on probability described how to calculate the probability of each possible outcome of a game of chance, the probability of the intersection of two outcomes (X and Y), the union of two outcomes (X or Y), and from these the expected value of the game. The training booklet on polygonal numbers defined a polygonal number, described how to draw the corresponding array, how to decompose the array into layers, and how to calculate the nth term and the sum of an arithmetic series. The training booklet on negative number bases defined positive and negative number bases, and described how to convert a numeral in any integer base to a numeral in base 10, and how to convert a numeral in base 10 to a numeral in any positive or negative integer base. In Exhibit 1 are excerpts from the text, and sample exercises for each lesson in each task.

Materials for Problem-Practice Phase

After students completed the four lessons in the training booklet for one task, they were given problems to solve which incorporated all four lessons of the training booklet. Accompanying each practice problem was a booklet of hints to enable every group in the group sessions, and every individual in the individual sessions, to solve the problems. The booklet of hints for a problem consisted of a step-by-step solution of the problem in 13 steps. In the booklets of hints, all formulas were described and all computations were carried out in detail. Excerpts from practice problems appear in Exhibit 1. Sample practice problems appear in Appendices A, B, and C.

Tests

Sample test items appear in Exhibit 1. The tests in full appear in Appendices D, E, and F. For each task in Part I there was an immediate test and a test at the next week's session. All students in Part II received the immediate test, but not the delayed test.

At the conclusion of the problem-practice phase of each session in Part I, each student received two test problems to solve. The first problem was an instance of the task encountered in that day's session. It was, then, an immediate test. The second problem served as a delayed test for the task of the previous session. The problem for each test had the same format as the problems solved during the problem-practice phase.

Other Materials

As there was no training or immediate test in the fourth session, students were given warm-up problems of algebra, computation, and arithmetic reasoning. The warm-up problems were unrelated to the content of the delayed test.

Exhibit 1

Excerpts from Training Booklets, Sample Problems in Problem-Practice, and Sample Test Items for Tasks A, B, and C

Task A	Task B	Task C
Excerpts from Training Booklets		
Lesson I	**Lesson I**	**Lesson I**
. . . Put four marbles, one red, one yellow, one green, and one blue, all the same size, into a box or jar that you cannot see through. Mix the marbles thoroughly. Without looking, suppose you reach in and draw one marble. . . . In this experiment, then, there are four possible outcomes: a red marble, a yellow marble, a blue marble, or a green marble. . . . Since a red marble is one of four equally likely outcomes we would expect that in many trials of the experiment we would draw a red marble about 1/4 of the time. . . . Thus, we assign to each of the four outcomes the probability of 1/4.	. . . We can form polygons inside polygons of the same shape. In the figure below, the smallest polygon has two dots on a side. The middle size polygon has three dots on a side. The largest polygon has four dots on a side. . . . An array of polygons inside polygons represents a polygonal number. The nth polygonal number is the total number of dots in an array in which the outermost polygon has n dots on each side. . . . The picture above represents the 4th polygonal number because the outside polygon has 4 dots on each side.	. . . Numerals written in different bases show different ways of grouping the same number of objects. Our system of counting is the decimal system, which is base 10. . . . The numeral 5379 written in expanded notation is $5(10)^3+3(10)^2+7(10)^1+9(10)^0$. . . . To express a numeral in base N as a base 10 numeral, write the given numeral in expanded notation. Then do the necessary multiplications and additions. For example, $4322_5 =$ $4(5)^3 + 3(5)^2 \div 2(5)^1 + 2(5)^0 =$ $4(125) + 3(25) + 2(5) + 2(1) =$ 587_{10}.
Exercise	**Exercise**	**Exercise**
If you toss an honest die once, what is the probability that the die lands with a 6 on the face of the die on the top?	Draw the picture that represents the 3rd triangular number.	Convert 321_4 to a numeral in base 10.

Exhibit 1 (continued)

Task A	Task B	Task C
Lesson II . . . This time, we draw a marble, write down its color, and then put it back into the jar. Then we draw a marble again, and write down the color of this one. We want to find out the probability that a red marble is drawn on both tries. In our notation we want to find out P (red on first draw and red on second draw) . . . = P (red on first draw) x P (red on second draw.	Lesson II . . . We can see this figure as three layers of dots. We always start with the one corner dot that is shared by all the polygons in the array. In our array, that dot is the uppermost dot. So the first layer has one dot. The next layer has all the dots in the smallest polygon except the one dot we already counted. So the second layer has four dots. The next layer has all the dots in the larger polygon except the four dots in the second layer and the one dot in the first layer . . . so the third layer has seven dots.	Lesson II . . . Given a numeral in base 10, how can we find its equivalent in another base? We can find it by doing successive division. We repeatedly divide the numeral in base 10 by the new base. We keep dividing until the quotient is zero. In the following example, we want to find the numeral in base 8 that is equivalent to 3146_{10}. We will use a chart that puts the quotient on the left and the remainder at each step on the right . . .
Exercise You have a spinner with lots of colors on it, and a normal die. What is the equation for the probability of blue on the spinner and a 6 on the top face of the die?	Exercise Decompose the figure below into layers of dots. How many dots are in each layer?	Exercise Convert 123_{10} to a numeral in base 3.
Lesson III . . . Here we want to find out the probability of drawing a red marble on the first draw or drawing a red marble on the second draw, or both. In our notation	Lesson III . . . In a series the numbers forming a sequence are added together. So the series of savings for the first four weeks is \$1 + \$2 + \$3 + \$4 = \$10.	Lesson III . . .Numerals written in a negative number base use the same digits (0,1,2,3,. . .)as in positive bases, but have powers of negative numbers as place values. For example, 34876_{-10}

Exhibit 1 (continued)

Task A	Task B	Task C
we want to find out P(red on first draw or red on second draw). . . .the probability of "red on first draw" or "red on second draw" is P(red on first draw) + P(red on second draw) - P(red on first draw and red on second draw).	. . .But let's look at a more complicated series: 1+4+7+10+ . . . It's easy to see that the sixth term is 16. But it's not easy to see what the 100th term is. We need a formula to find the nth term in the series. . . . To find the nth term, just use the formula . . .	represents a numeral in base -10. Writing the expansion of this numeral we have . . . . . .The terms of the expansion in a negative number base will alternate in sign. A negative number raised to an even power is positive. A negative number raised to an odd power is negative. . . .
Exercise You have a spinner with lots of colors on it, and a normal die. What is the equation for the probability of blue on the spinner or a 6 on the top face of the die?	**Exercise** In the series 1 + 4 + 7 + . . . what is a? What is d? What is the 50th term in the series?	**Exercise** Convert 423_{-5} to a numeral in base 10.
Lesson IV Suppose the experiment we have described is really a game with a dollar value attached to each marble. If you draw a red marble, you win \$2. If you draw a yellow marble, you win \$1. But if you draw a green marble or a blue marble, then you don't win anything at all. . . . The expected value is actually the average winnings you could expect to take home if you play this game many times. . . . The average winnings over all the times you play is the expected value of the game.	**Lesson IV** . . . the series is 1+2+3+ . . . +n. What is the sum of these numbers? If n is small, we can easily find the sum. . . . If n is large, . . . we need a formula for the sum of n terms in a series. To find the sum of n terms in an arithmetic series, use the formula . . .	**Lesson IV** . . . Given a numeral in base 10, how can we find its equivalent in a negative number base? We can find it by doing successive division. We repeatedly divide the numeral in base 10 by the new base. We keep dividing until the quotient is zero. The tricky part is that we always want a nonnegative remainder at each step. . . . Let's review the rules for dividing and multiplying positive and negative numbers . . .

Exhibit 1 (continued)

Task A	Task B	Task C
. . . To find the expected value of the game, multiply each value of a draw by its probability, then add these results.		. . . In the following example we want to find the numeral in base -3 that is equivalent to 26_{10} . . .
Exercise Using the spinner in question one, suppose you win $50 if the pointer lands on violet, $25 if the pointer lands on yellow, and nothing if the pointer lands on red, orange, green, blue, or indigo. What is the equation for the expected value of this game?	Exercise In the series $1+3+5+7+\ldots+(2n-1)$ what is the sum of the first n terms? (Hint: $2n-1$ is the last term.)	Exercise Convert 14_{10} to a numeral in base -3.
Sample Problems in Problem-Practice		
Suppose you play a gambling game at a Las Vegas Casino. In this game you have to do two things. First you have to spin a pointer on a spinner that has four colors: red, blue, yellow, and green. Each color is equally likely. Second you have to toss an honest six-sided die. You win $50 if the pointer lands on red or if the die comes up showing 4. If anything else happens you don't win anything. What is the expected value of this game?	Find the formula for the nth hexagonal number.	You are on an interplanetary mission aboard the Starship Enterprise. . . . Your role is that of a Federation accountant and diplomat. Your mission is to collect money from Omega I, II, and II to give to Alpha I and II to help pay for damages. . . . Your accounting skills are needed because the monetary system of each planet is in a different base. . . . you were given the following information. . . . How much will each planet receive in its own base?

Exhibit 1 (continued)

Task A	Task B	Task C
Sample Test Items		
At the same Las Vegas Casino you want to try your luck at another game. . . . you win $10 if the card you draw is the 10 of diamonds or if the pointer lands on green--otherwise you win nothing. What is the expected value of the game?	Find the formula for the nth triangular number. (Formulas you may want to use: nth term = . . . sum = . . .)	It is now a year after your return from your mission aboard the Starship Enterprise. Federation Headquarters has asked you to return to the planetary system. . . . You have the following information for your mission . . . convert the money to the proper bases for Alpha I and II.

During the fourth session, a questionnaire elicited reactions to learning individually and learning in groups. The questionnaires were also used to compare students' perceptions of group process with the experimenter's observations of group process.

Procedure

Part I

Training. The procedure during the training phase was identical for all students and all sessions. Training was conducted by the experimenter; in some sessions an aide was present. At the beginning of a session, the four students in a group entered a room. They were seated with no more than one to a table.

No student could see the work of another. In the first session, the experimenter briefly explained the nature of the study and the procedure. The experimenter described the purpose of the sessions: that participants learn the material they would receive. Students were informed that they would be tested on the material later in the session and in a future session.

After preliminary instructions were given, the experimenter distributed instructions for the training phase of the session, the training booklets, and answer sheets for the exercises at the end of each lesson. After every student had read the instructions silently, the experimenter read the following aloud:

> You will now learn four parts of a problem [task].[1] Each part has one or more pages of written material, followed by several problems [exercises] for you to solve.
>
> You should read the material for Part I [Lesson I], solve the first two problems [exercises] at the end of the section, and show your solutions to the person you are assigned to check your work. That person will then tell you when to go to Part II [Lesson II].
>
> If at any time you have questions or problems, please ask the person you are assigned to help you.
>
> You will have plenty of time to learn everything in this booklet. So work at your own pace. Please do not write in the booklet.

---

[1] Here and in other instances, terminology used with the subject differed from that appropriate in this report. Words in brackets translate this statement into the usage of the report.

At this time the experimenter introduced the aide, if any, to the group. Two students were asked to check their work with the experimenter; the remaining two students checked their work with the aide. The experimenter emphasized that each student should solve only two exercises at the end of a lesson, unless later given other instructions.

All students in a group started work on the training booklets simultaneously. As soon as a student finished the first two exercises at the end of Lesson I, the student brought his or her solutions to the experimenter or aide. If the solutions were correct, the experimenter asked if the student understood the material, or had questions or comments. If the student had no questions and indicated that he or she understood the material, the experimenter instructed the student to read the next lesson and answer the first two questions at the end of the lesson, and then check with the experimenter. If any student indicated confusion, the experimenter explained the important points until the student was satisfied. If the student remained uncertain, the experimenter asked the student to do the next exercise for practice. If a student's solution to either of the first two exercises was incorrect, the experimenter explained the error and showed the student how to solve the problem. Then the experimenter asked the subject to do one or two more exercises at the end of the lesson. The experimenter repeated this procedure until every student obtained the right answer to an exercise and indicated that he or she understood the material.

The time limit for the training phase was uniform for all students: 30 minutes in the first session, 45 minutes in the second session, and 40 minutes in the third session. If a student finished all four lessons in the training booklet before the time limit, the experimenter asked the student to work on exercises that had been passed over. The student was instructed to do these in order, finishing all exercises in one lesson before starting exercises in the next lesson. The experimenter asked the student to check the solutions with her after every two or three exercises. The training booklets included enough exercises to occupy all time allotted to training. At the end of the time, the experimenter collected all training booklets and answer sheets.

Problem-practice. During the problem-practice phase of the session, students solved problems that called upon the components of the task learned during the training phase. Problem-practice was done individually in the first session of Part I and in both sessions of Part II. During individual problem-practice, all students stayed in their original seats. The experimenter distributed the instructions, practice problems, answer sheets, and booklets of hints. After students had read the instructions silently, the experimenter explained how to use a booklet of hints:

> This is a booklet of hints to help you solve the problems. You do not have to use the hints if you don't need them. You can use hints in any order. They are to help you if you have any difficulty.
>
> If you use any hints, please write down on your answer sheet which hints you use. Mark the number of each hint that you use as you go along, rather than waiting until you finish the problem. In this way you will not have to worry about forgetting which hints you used.
>
> When you finish the problem, please look at hint No. 13. Hint No. 13 has the answer on it. If your answer matches the answer on the last page of the booklet (hint No. 13), then bring your paper to me. If your answer does not match the answer given in hint No. 13, then use the hints to see where you got off the track. You may have made a calculation error, or may have used the wrong equation in one step of your solution. If you do use the hints to help you figure out where you went wrong, please note which hints you used. As soon as you are satisfied that your answer agrees with the answer in hint No. 13, then bring your paper to me. It is important that you bring your paper to me after each problem that you solve.
>
> If you have any questions, please ask them. You will have plenty of time to work in this session, so please take as much time as you want.

The experimenter explained that it was important that everyone understand how to solve the problems in this phase of the session, and not merely copy the hints. Students were again told that they would be tested on the task.

All students started work on the problems simultaneously. As soon as a student finished the first problem, he or she brought the solution to the experimenter for checking. If a student's answer was incorrect, the experimenter asked the student to look at the hints to locate the mistake. If a student asked for help or asked a question, the experimenter explained that the answer to the question was in the hint booklet. In no instance did a student ask a question that could not be answered using the hints. When a student brought a correct solution to be checked, the experimenter asked if the student understood how to solve the problem. If a student indicated any confusion, the experimenter explained the confusing part. If a student indicated no confusion, the experimenter asked the student to go on to the next problem. The experimenter repeated the procedure until the time limit was reached. The time limit for the problem practice phase in the individual session was 20 minutes. At the end of 20 minutes the experimenter collected all materials.

During the problem-practice phase of the second and third sessions in Part I (group condition) all students sat at one table, facing a one-way mirror. The experimenter explained that the mirror was one-way and that the session would be recorded on an audio recorder. The group was told that the observation room behind the mirror would be visited after the session was over.

The trainer handed to group members the instructions for group problem-practice. After students read the instructions silently, the experimenter read them aloud:

> In this part [phase] of the session you will solve one or more problems in a group. The problems are based on the material you have just learned. You have learned all the material you will need to be able to solve the problems.
>
> The purpose of solving the problems in a group is to help everyone in the group learn how to solve the problem. After you solve the problems in your group, you will be given a problem to solve by yourself. Your group's score will be how well everybody in the group does on the test problem.
>
> To give your group a good score you should help each other to learn. If you have a question or have trouble following what's going on, ask the group to explain it to you. If you notice someone not understanding something, you should explain it to him or her. The better everyone understands how to do the problem, the better your group's score will be.
>
> Always work as a four-person group. Do not divide the work into teams.
>
> As in the session last week, you will have a booklet of hints to help you solve each problem. As before, you can use any or all hints, in any order. Be sure to write down the numbers of any hints your group uses. The answer to a problem is in hint No. 13 at the end of the booklet. If your answer does not match that in hint No. 13, then use the hints to see where your group got off the track.
>
> As soon as you are satisfied that your answer matches the answer in the booklet, then pick up problem No. 2 and the booklet of hints for that problem. Follow the same procedure for that problem. When your answer matches the answer in the booklet for problem No. 2, go on to problem No. 3. Work on only one problem at a time.

> You will have plenty of time, so take as much time as you need.
> I will signal your group when this part of the session is over.

As soon as all group members understood the procedure, the experimenter gave the group the first problem, one answer sheet, and the booklet of hints for that problem. All members of the group shared the problem sheet, the answer sheet, and the booklet of hints. The group was instructed to pick up the next problem and the next hint booklet when it finished the first one.

The group worked on practice problems until time was called. The time limit for problem-practice was 22 minutes in the second session and 25 minutes in the third session. The experimenter allowed a group to work for an extra two minutes if it was close to solving a problem. Through the one-way mirror the experimenter observed the group as it worked. What group members said was recorded on one channel of an audio recorder. The experimenter identified each speaker by number on the other channel of the recorder. After time was called, the experimenter collected all materials.

Testing. After problem-practice all students returned to their original tables or desks. The experimenter distributed the immediate test problem and answer sheet. Students were instructed to write out all their work in the solution to the problem. As soon as a student finished the immediate test the experimenter exchanged it for the delayed test. During testing, the subjects were not permitted to use hints or other materials. The experimenter did not answer questions related to the content of the problems. There was no time limit for either test.

Fourth session. A fourth session was needed for the delayed test on the task in the third session. At the start of the fourth session, the experimenter distributed a set of 15 warm-up problems and an answer sheet to every student. The group was told that each person should work on any three or four problems, in any order, and show his or her solutions to the experimenter. Each student worked individually. When a student showed work to the experimenter, she answered the student's questions and corrected any errors. If time remained, the student was asked to select three more problems to solve. The time limit for the warm-up was 15 minutes.

Following the warm-up problems, students worked on the delayed test individually and without hints or help from the experimenter. There was no time limit. When a student turned in the delayed test, he or she was given a questionnaire about learning in the individual and group settings.

Part II

The procedure in both sessions of Part II was identical to the procedure in the individual session (first session) of Part I. Two individual sessions, one week apart, included training, problem-practice, and testing. All students solved problems on Tasks A and B, one task in each session. During the problem-practice phase any student who completed all problems before the time limit was asked to make up and solve problems similar to the ones given. The time limits in Part II were the same as in Part I.

Data Collection

During training, problem-practice, and testing, the experimenter recorded the time taken by each student for each phase of every session. Times were recorded to the nearest minute.

All posttest and delayed test problems were scored on a 20-point scale. The four stages of the problem corresponding to Lessons I, II, III, and IV were scored separately and the scores were added together. A score of zero was given only when the student made no mark on the answer sheet.

The answer sheet in problem-practice also showed which hints the student had used. Information on hints was available for all students in individual and group sessions.

CHAPTER III

PRELIMINARY ANALYSES AND METHODOLOGICAL DECISIONS

Chapter III focuses on the methodological decisions made prior to analysis. The first section describes the assignment of subjects to groups and the formation of the aptitude variable used in all analyses. The second section describes the measurement of the dependent variables: test scales, properties of score distributions, and the decision to perform nonparametric analyses. The third section describes the units chosen for various analyses. The final section describes the nonparametric inferential statistics used.

Assignment of Subject to Groups and Formation of Aptitude Variable

Assignment of Subjects to Groups

In Part I of the study, stratified random sampling was used to assign students to twelve groups. Three ability strata were defined--high-ability, medium-ability, and low-ability--according to scores on ability factors G_c (scholastic ability) and G_f (nonverbal spatial-analytic ability). Of the twelve groups, two were of uniform high-ability, two were of uniform medium-ability, two were of uniform low-ability, and six were of mixed ability. Four high-ability students were selected at random to form each of the two uniform high-ability groups. One high-ability student was randomly chosen for each of the six mixed-ability groups. The pattern of assignment was the same for low-ability and medium-ability students, except that two medium-ability students were assigned to each mixed-ability group.

Definition of Aptitude Variable

In the factor scores G_f and G_c, verbal achievement test scores were weighted more heavily than quantitative achievement scores. Only a portion of the variance in the quantitative scores was contained in factors G_f and G_c. Because the tasks used in the study were quantitative, an ability continuum that better represented quantitative ability was desired. To determine whether the quantitative variables could add to the prediction of outcome by G_f and G_c, stepwise multiple regression analyses were carried out. The G_f and G_c factor scores were entered into stepwise multiple regressions predicting each posttest. The factor scores were entered first, then the quantitative variables were entered. Beyond the variance in posttest scores accounted for by G_f and G_c, the quantitative variables together explained 5 percent to 20 percent of the variance. Because the quantitative variables would add predictive power, they were combined with G_f and G_c to form a new aptitude variable.

A composite quantitative variable was formed from all available quantitative achievement and ability scores. Each of four quantitative scores was standardized using the mean and standard deviation of the sample of 48 subjects in Part I of the study. The standardized scores were then summed to produce the quantitative composite. The G_f and G_c factor scores and the scores on the quantitative composite were standardized in turn using the mean and standard deviation of the sample of 48 students. The three standardized scores were summed to form a new ability variable (G). G is the aptitude variable in all analyses to be presented.

The top row in Figure 5 shows the scores of the 48 students on G. The G distribution of the 48 students had a mean of zero and a standard deviation of 2.42. To form ability categories, the range of G was divided into four equal intervals. Most students retained their original classification as high, medium, or low.

In Part II of the study, 18 students were selected at random. The second row in Figure 5 shows the scores of the students in Part II. Among the 18 students, G had a mean of -.12 and a standard deviation of 2.15.

Reclassification of Groups

Groups were reclassified as uniform or mixed on G. One group designated as mixed-ability (MA) according to G_f and G_c became a uniform-ability (UA) group when classified using G. After reclassification, seven groups were of uniform ability and five were of mixed ability. (See Table 3)

Replacement of G_f and G_c with G did not change the ranking of students within MA groups. Thus, the student in a group who had the highest composite of G_f and G_c also had the highest G score. Likewise, the student lowest on G_f and G_c was lowest on G. Reclassification on G did, however, change the ability composition within groups. In the G_f and G_c classification, high-ability students in UA groups and in MA groups had comparable ability. The same is to be said at the medium-ability and low-ability levels. When ability was defined by G some comparability was lost. By chance, the middle students in MA groups had lower G scores than medium-

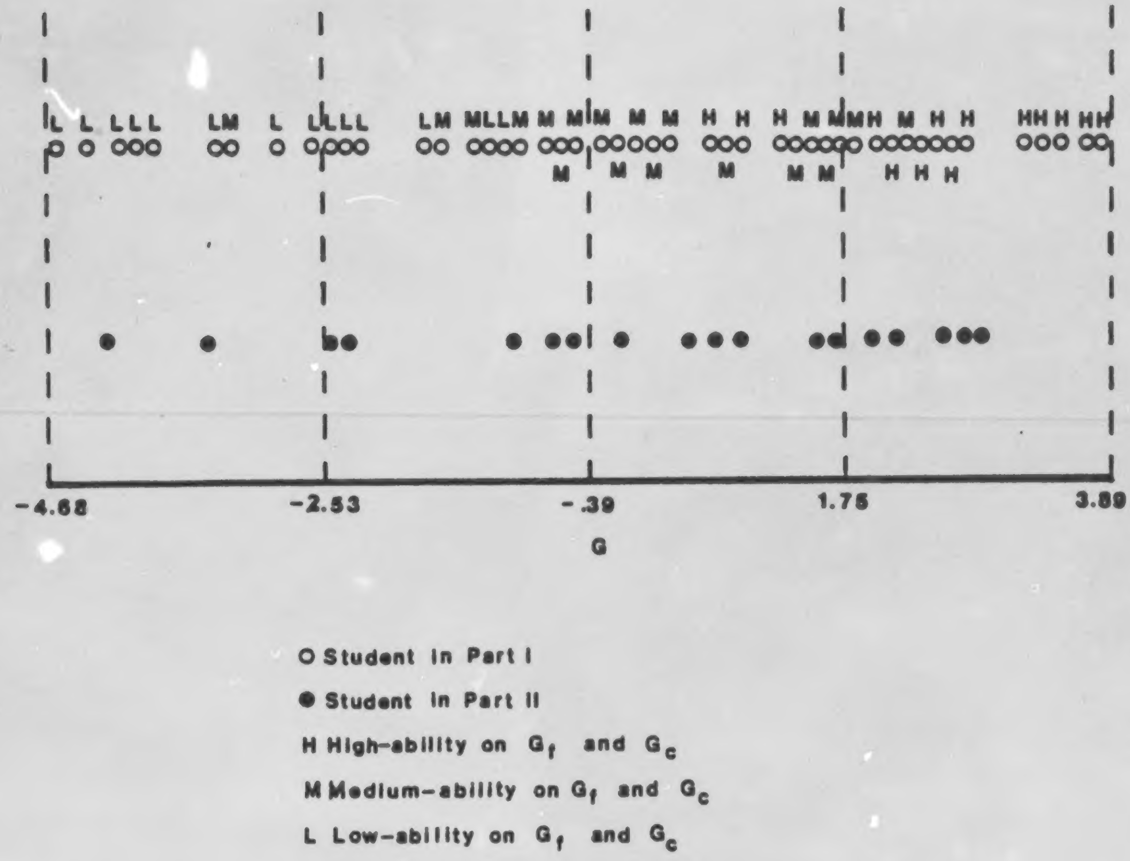

Figure 5. G scores of every student in Part I and Part II.

Table 3

The G Mean and Standard Deviation of Each Group

Group Composition	M	SD
Mixed-ability	- .6	2.6
	- .8	3.6
	.2	2.5
	.0	3.3
	- .8	2.8
Uniform-ability		
High-ability	2.0	1.1
	2.6	1.3
Medium-ability	.8	1.6
	.7	1.5
	.8	1.6
Low-ability	-2.4	.7
	-2.4	1.2

ability students in uniform-medium-ability (UMA) groups. The lowest student in MA groups had lower G scores than low-ability students in uniform-low-ability (ULA) groups. The ability of the high-ability member of MA groups remained about equal to that of students in uniform-high-ability (UHA) groups.

Measurement of Dependent Variables: Test Scales and Distributions

Each immediate and delayed test was scored on a scale with a maximum of 20 points. Each test was scored in four parts; a part corresponded to a lesson learned during the training phase of the session. Two parts, corresponding to the easier lessons, had a maximum of four points each. Two parts, corresponding to the more difficult lessons, had a maximum of five points each. A maximum of two points was awarded for algebraic and arithmetic manipulations needed outside the four parts. The scales were designed so that equal scores on two tests would signify equal degrees of mastery.

The tasks proved not to be equally difficult. Some students reported that they found Task B more difficult to learn than Tasks A and C. The scores on the tests bear out their remarks; most often students did their poorest work on Task B. In a larger study, the order of tasks would be counterbalanced to distinguish task difficulty, order, and condition effects.

The distribution of immediate and delayed test scores were far from normal. (The distribution of G scores, however, was normal.) On each immediate task, the median was close to the perfect score of 20, showing a marked ceiling effect. On all immediate tests, over half of the students achieved perfect scores. In contrast, the delayed test scores on Task B exhibited a floor effect; over a third of the scores were near zero. Because the test scales were designed to be meaningful across tests, the scales were not transformed. Ties were so numerous that no transformation would have achieved normality.

Statistical methods based on the assumption of normality would produce distorted conclusions. In this study, then, nonparametric procedures were applied extensively. Unless otherwise stated, all inferential statistics were obtained using nonparametric techniques. All statistical tests and confidence intervals reported are distribution-free, but not necessarily invariant under transformation of scale.

Units of Analysis

All students learned Task A as individuals. Although they learned in the presence of other students, no interaction took place. Students learning Task A were considered to be independent; what one student did had no effect on what another learned. Thus, in Task A, the individual was a proper unit of analysis and the analysis of cases pooled would clearly be meaningful.

In Tasks B and C in Part I, however, students learned in interacting groups. They were instructed to work together to solve problems and to help each other learn how to solve them. What one student did could have a great effect on what another learned.

The learning by a student could have depended in part on the aptitude level of the group as a whole. For example, a high-ability group might have solved more problems in the problem-practice phase. As a result, the group as a whole might have learned much. But it is possible that the rapid progress may have prevented understanding.

Learning could also have depended on the student's relative standing within the group. Thus, if the group learning experience was beneficial to the lowest member of the group, perhaps because explanations were given by superior members, the medium-ability student would have been better off in a high-ability group. The learning by an individual, then, would have depended upon characteristics and behavior of fellow members.

Students cannot, therefore, be considered independent. To designate the individual as the unit of analysis in Tasks B and C would be untenable. For Tasks B and C in Part I, the group will be the unit in most analyses reported.

Unless otherwise specified, medians and means on tasks were computed from group means. The group mean on Task A was the mean score of members working singly in the presence of other students, not of interacting members. In Part II the group mean on Task B was also the mean score of members working singly in the presence of other students. Learning singly in the presence of others will be labeled "individual condition." The group mean on Task B or C in Part I was the mean score of interacting members. Learning in interacting groups will be labeled "group condition."

Nonparametric regression and correlation coefficients in most analyses were obtained using group means. It is well known that if groups are formed on the basis of a variable x, and the regression of outcome on x is linear in the population, the regression coefficient will be the same in the population whether the group or the individual is the unit of analysis. But when the predictor variable in the regression contains any component related to outcome and not to the grouping variable, the between-groups regression coefficient will differ systematically from the regression over all cases in the population (Burstein, 1975; Cronbach, 1976). In this study, groups were formed on the basis of factors G_f and G_c, but either G or immediate test performance was the predictor variable in the regression analyses. Because the results in the population would depend on the unit of analysis, and the group was the only logical choice for unit of analysis in Tasks B and C, the group was chosen as the unit for regression analyses in all tasks.

In the section on reliability of learning, however, nonparametric regression and correlation coefficients to be reported were calculated from individual scores, not group means. The regression analyses used performance on Task A as a predictor of performance on Task B and on Task C. All students in Parts I and II of the study learned Task A as individuals. The analysis of reliability in Part I compared scores on a task learned in the individual condition (Task A) with scores on a task learned in the group condition (Task B or C). The analysis of reliability in Part II examined stability across two tasks learned in the individual condition (Tasks A and B).

Statistical Estimation and Inference

Measures of Central Tendency

Medians will be reported. Where there were ties at the score interval including the 50th percentile, the median was computed by interpolation.

For differences across tasks in the same sample (comparing individual and group conditions) distribution-free confidence intervals for the difference in medians were computed by means of the Sign Test; these took advantage of the repeated-measures design. For differences across tasks of different samples (comparing uniform and mixed ability groups) distribution-free confidence intervals for the difference in medians were computed by means of Wilcoxon's Rank Sum Test. In view of the fact that samples were stratified, the tests assuming random sampling are conservative.

Measures of Association

Because the data contained a large number of tied ranks, Kendall's tau was the measure of association reported. Nonparametric estimates of the regression coefficients were calculated. The estimator of β (β^*) was developed by Theil (1950) and generalized by Sen (1968) to the case where the x's need not be distinct. The unbiased estimator of β is the median of all possible slope values that could be computed from the data. A sample slope value is the difference in the dependent variable divided by the difference in the independent variable for a pair of observations. The estimator β^* is distribution-free, but not invariant under transformations of scale. The procedure for computing the distribution-free confidence interval for β, (β^*_L , β^*_U), is described in Appendix G.

When there are ties on the dependent variable, there may be many zero slope values. Thus, a risk of this nonparametric procedure for calculating the point estimator β^* is that an estimate of zero may be obtained. The same risk applies to the bounds of the confidence interval for β.

CHAPTER IV

TEST RESULTS

Review of Research Questions

This study was designed to compare learning by students in interacting groups with that by students working singly. The main problem was to determine how learning differed in the two conditions. Group process will be examined in Chapter V. The present chapter concentrates on test results of outcomes and aptitude.

Students learned one task (Task A) in the individual condition and two tasks (B and C) in the group condition. Students were given immediate and delayed tests on all tasks. The decline in performance from immediate to delayed tests is described in the first section. Performance is compared across conditions in the second section. Groups of mixed ability and uniform ability are compared in the third section.

Also of interest was the reliability of individual learning and learning in groups. Part II of the study, in which the students worked singly on Tasks A and B, was designed to obtain reliability data on individual learning. In Part I, students learned two tasks in the group setting; a comparison provides information on reliability of learning in groups. Reliability is examined in the fourth section. Interactions of ability and grouping are reported in the final two sections of this chapter.

All results to be reported are limited by the small sample size of the study. For some results, inference to population parameters is reported, but with so small a study few effects are expected to be significant. Noteworthy trends will be discussed, even if not statistically significant. To avoid redundancy, most nonsignificant results will not be qualified.

Level of Performance on Immediate and Delayed Tests

The medians and means in Table 4 indicate that on every immediate test many students showed excellent performance. On every immediate test about half of the students obtained perfect scores.

Students with high G scores did better, on the average, than those with low G scores. On most tests high medium ability students did almost as well as high ability students. Low medium ability students performed

Table 4

Medians, Means, and Standard Deviations of Ability and Outcomes for all Conditions and Tasks (All values are calculated from group means)

Condition, Task, and Test	Mdn	M	SD
Pretest data			
G (Part I, 12 groups)	.0	.0	1.5
G (Part II, 5 groups)	.4	.4	.9
Posttest data			
Individual condition			
Task A (Part I, 12 groups)			
Immed. test	18.2	17.5	2.4
Delay. test	13.6	14.2	3.7
Task A (Part II, 5 groups)			
Immed. test	18.5	17.8	2.0
Task B (Part II, 5 groups)			
Immed. test	18.5	18.1	1.2
Group Condition			
Task B (Part I, 12 groups)			
Immed. test	17.6	16.5	4.4
Delay. test	9.9	10.3	5.9
Task C (Part I, 12 groups)			
Immed. test	18.0	17.8	2.5
Delay. test	13.4	12.8	5.7

better, in general, than low-ability students, but less well than high-medium-ability students.

In Figures 6, 7, and 8 delayed test scores on one task are plotted against immediate test scores on the same task. Students falling on the 45 degree line had equal scores on immediate and delayed tests. It is seen that in Task A, decline occurred primarily among lower-ability students. In Tasks B and C, not only the lower-ability students, but many higher-ability students showed a marked decline in performance.

In Task A, only lower-ability students declined from immediate to delayed test. Most of the high-ability and high-medium-ability students performed well on the immediate test and equally well one week later. Almost half of the low-medium-ability students and some of the low-ability students achieved perfect or near perfect scores on the immediate test. Only rarely did a student remember most of the task one week later, however. Nearly every student with mediocre initial performance did still worse on the delayed test.

On Tasks B and C, the decline in performance from initial learning to the delayed tests was marked in every ability category. As in Task A, the higher-ability students did well on the immediate test, yet many did poorly on the delayed test. On Task B, over a third of the high-ability students showed a decline in performance. On Task C, a third of the high-medium-ability students showed this decline. Among lower-ability students, roughly half performed well on the immediate test and then performance declined markedly. On Task B, over half of the lower-ability students obtained zero or near-zero scores. On Task C, nearly a third obtained near-zero scores. Only one student had performed as poorly on Task A.

In summary, higher-ability students learned every task well initially, but they tended to consolidate Task A better than Tasks B and C. Though many lower-ability students learned well initially, few could perform any of the tasks adequately a week later.

Outcomes in the Individual Condition and in the Group Condition

As can be seen in Table 5, the average group performed well on the immediate test in either individual or group condition. The largest difference between medians is between Task B in Part I (group condition) and Task B in Part II (individual condition). The difference is .9 points

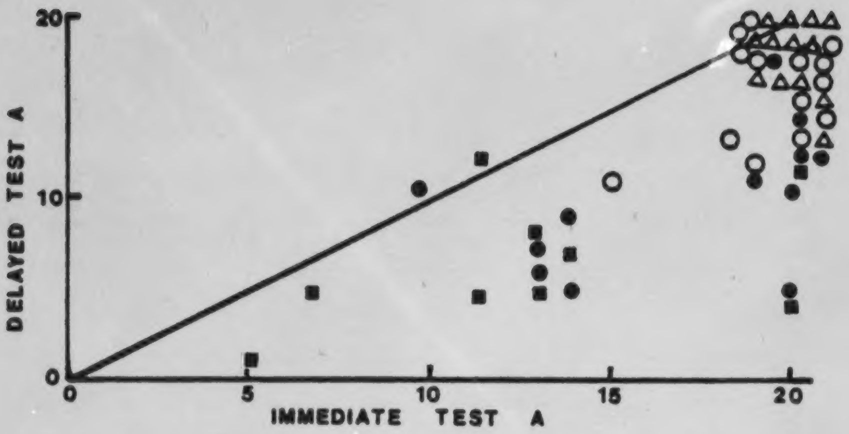

Figure 6. Scores of students on Task A immediate test versus Task A delayed test.

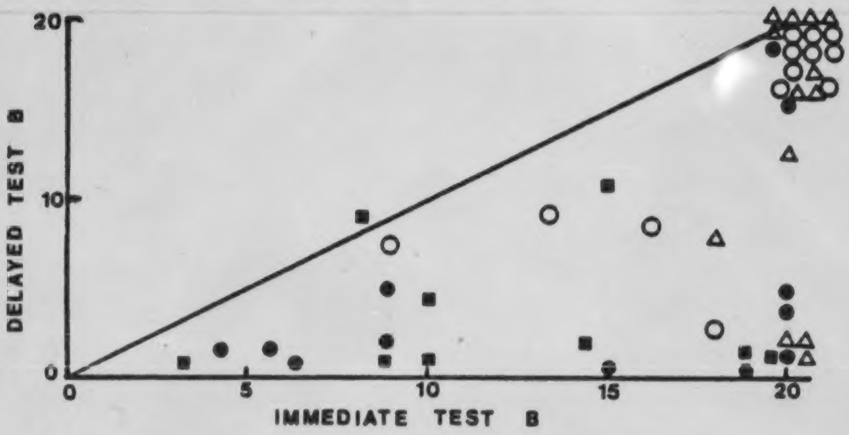

Figure 7. Scores of students on Task B immediate test versus Task B delayed test.

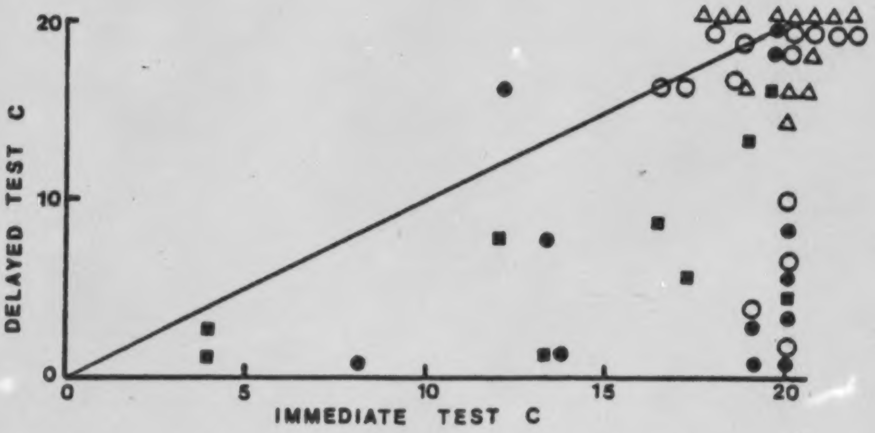

Figure 8. Scores of students on Task C immediate test versus Test C delayed test.

△ High-ability student ○ High-medium-ability student

● Low-medium-ability student ■ Low-ability student but the 95 percent confidence interval for the difference is $-4.5 \leq \Delta \leq 1.5$. No other difference between medians was statistically significant. All differences between means are small and statistically nonsignificant.

On delayed tests, fewer comparisons can be made because students in Part II did not take the delayed tests. In Part I, the A to B comparisons show superior results in the individual mode, but Task B was notoriously difficult. The A to C comparisons show little or no difference.

Outcomes in Uniform-Ability and Mixed-Ability Groups

The preceding analysis did not distinguish between types of grouping. Table 5 presents medians and means for uniform and mixed-ability groups. With mixed-ability (MA) grouping, immediate test performance was better after learning in the group condition but delayed performance was about the same as that after learning in the individual condition. With uniform-ability (UA) grouping, immediate performance was about the same in group and individual conditions but delayed performance was better after learning in the individual condition than in the group condition. UA groups did about as well on the immediate test on Task B (group condition) as on Task A (individual condition). But their delayed performance on Task B was poor. UA groups performed better on the Task C delayed test than on Task B, but still worse than on Task A. MA groups did *better* on the difficult Task B immediate test than on Task A, and no worse on the delayed test. MA groups again showed superior performance on Task C.

UA groups had, on the average, higher mean ability than MA groups. Their learning in the group setting, however, was not consistently better than that in MA groups. In Task A (individual condition) UA groups performed better than MA groups, which is consistent with the difference in ability. In Tasks B and C (group condition), the margin between UA and MA groups on the immediate test was narrow. On the delayed test on Task B, UA groups did *worse* than MA groups. The difference was five points, but the 95 percent distribution-free confidence interval based on Wilcoxon's Rank Sum Test was $-11.0 \leq \Delta \leq 8.8$. Because of the large variation in group means this interval is wide. It contains zero. On the delayed test on Task C, the margin between UA and MA groups was very slim.

Data on uniform-ability groups by ability level appear in Table 5. With one exception (high-ability groups on Task B), decline in performance from immediate to delayed test is proportional to ability. Comparing performance on Task A with that on Tasks B and C shows that the

Table 5

Medians, Means, and Standard Deviations of Ability and Outcomes in Part I for Uniform-Ability and Mixed-Ability Groups

(All values are calculated from group means)

Condition, Task, and Test	Uniform-Ability								
	Low (2 groups)			Med (3 groups)			High (2 groups)		
	Mdn	M	SD	Mdn	M	SD	Mdn	M	SD
Pretest data									
G	-2.4	-2.4	.0	.8	.8	.0	2.3	2.3	.4
Posttest data									
Indiv. Cond.									
Task A									
Immed. test	16.4	16.4	5.1	19.2	19.1	.8	19.8	19.8	.0
Delay. test	8.5	8.5	2.1	16.2	16.4	1.5	19.4	19.4	.2
Group Cond.									
Task B									
Immed. test	10.6	10.6	6.9	19.9	19.9	.1	18.4	18.4	1.6
Delay. test	1.4	1.4	.5	18.2	15.1	6.4	10.4	10.4	5.5
Task C									
Immed. test	14.1	14.1	4.4	20.0	20.0	.0	19.2	19.2	.0
Delay. test	3.5	3.5	2.8	14.5	14.6	3.9	19.0	19.0	.7

Condition, Task, and Test	Uniform-Ability (Groups pooled, 7 groups)			Mixed-Ability (5 groups)		
	Mdn	M	SD	Mdn	M	SD
Pretest data						
G	.8	.3	2.0	- .6	- .4	.4
Posttest data						
Individual condition						
Task A						
Immed. test	19.7	18.5	2.6	15.8	16.2	1.2
Delay. test	16.2	15.0	4.8	13.2	13.2	1.1
Group condition						
Task B						
Immed. test	19.5	16.8	5.2	17.5	16.0	3.4
Delay. test	7.8	9.8	7.5	12.8	11.0	3.4
Task C						
Immed. test	19.4	18.1	3.3	17.6	17.4	1.0
Delay. test	14.5	12.7	7.0	13.2	13.0	3.7

individual condition was better at all levels of ability. The only exception was that on immediate tests, medium-ability groups did slightly better in the group condition.

Performance According to Rank on Ability Within a Group

The above analyses consider only average group performance. The student's comparative position within the group apparently had an effect. This section examines the performance by students in light of their ability rank within the group.

Table 6 gives medians of outcomes for students at ranks 1 (high), 2 (medium), and 3 (low) within UA and MA groups. Students could have been ranked as 1, 2, 3, and 4 on G, but the middle two students were not distinguished in this analysis. Both were assigned rank 2. The high member of an MA group had ability comparable to that of the average member of a UHA group. The middle member of an MA group had somewhat lower mean G scores than the average student in UMA groups. The low member of an MA group had slightly lower mean G scores than the average student in ULA groups.

As can be seen in Table 6,high-ability students performed well on immediate tests whether they learned in an MA group with less-able students,or in a UHA group with students of comparable ability, or singly. As already seen in Table 5,highs in UHA groups forgot much of their initial learning of Task B. We now see in addition that the student who had the greatest difficulty was the least able member of a UHA group. More important, there was no such decline for highs in MA groups.

Table 5 reported that performance of medium-ability students on immediate tests was better after learning in the group condition than after learning in the individual condition. Table 6 now shows that this was true only of UMA groups (except for the highest members in UMA groups). In MA groups, the group condition was often detrimental to performance of medium-ability students.

Medium-ability students in MA groups did worse on one immediate test and both delayed tests after learning in the group condition than on tests after learning in the individual condition.

As shown by Table 5, low-ability students in ULA groups did better on all tests after learning in the individual condition than after learning in the group condition. According to Table 6, especially the least

Table 6

Medians and Standard Deviations of Ability and Outcomes
by Rank within Uniform-Ability and Mixed-Ability Groups
(All values are calculated from individual scores)

	Within-Group Rank on Ability					
	Low		Middle		High	
Condition, Task, and Test	Mdn	SD	Mdn	SD	Mdn	SD
Uniform-low-ability (n=2;4;2)[a]						
G	-3.7	.5	-2.4	.2	-1.3	.3
Task A						
Immed. test	15.5	6.4	14.5	3.8	16.5	5.0
Delay. test	5.0	1.4	8.0	3.8	11.0	4.2
Task B						
Immed. test	6.0	4.2	11.5	6.5	13.5	9.2
Delay. test	.5	.7	1.5	2.6	.5	.7
Task C						
Immed. test	8.0	5.7	18.5	3.1	13.5	7.8
Delay. test	4.5	5.0	5.5	2.9	.0	0
Uniform-medium-ability (n=3;6;3)						
G	-1.1	.4	.2	.9	2.4	.2
Task A						
Immed. test	18.5	3.5	19.5	.8	19.8	.6
Delay. test	14.0	7.6	17.5	2.6	19.0	1.0
Task B						
Immed. test	19.8	.6	20.0	.0	20.0	.0
Delay. test	16.0	9.2	19.5	5.6	13.0	9.2
Task C						
Immed. test	20.0	.0	20.0	.0	20.0	.0
Delay. test	19.0	11.3	19.5	9.2	17.0	2.1
Uniform-high-ability (n=2;4;2)						
G	1.0	.2	2.4	.9	3.6	.4
Task A						
Immed. test	19.5	.7	19.8	.5	20.0	.0
Delay. test	19.5	.7	19.5	1.0	19.5	.7
Task B						
Immed. test	17.0	1.4	18.8	3.5	20.0	.0
Delay. test	5.5	5.0	11.0	8.2	11.0	2.7
Task C						
Immed. test	18.0	.0	19.8	.5	19.5	.7
Delay. test	18.5	2.1	19.7	1.0	18.5	.7

Table 6 (continued)

	Within-Group Rank on Ability					
	Low		Middle		High	
Condition, Task, and Test	Mdn	SD	Mdn	SD	Mdn	SD
Mixed-ability (n=5;10;5)						
G	-4.1	.7	- .1	1.5	2.3	1.1
Task A						
Immed. test	12.8	4.1	19.2	4.1	19.9	.4
Delay. test	5.0	3.0	13.0	3.9	18.8	2.3
Task B						
Immed. test	10.2	5.6	16.5	5.5	19.8	.9
Delay. test	2.3	3.6	11.5	2.7	18.5	5.0
Task C						
Immed. test	19.0	6.8	19.2	3.4	18.2	1.3
Delay. test	10.0	5.9	10.5	6.9	19.0	1.6

[a] Numbers in parentheses are sample sizes at each rank within ability level.

able member of ULA groups had trouble with the tasks. In MA groups, however, lows actually did better on immediate and delayed tests on Task C (group condition) than on Task A (individual condition). Although they showed some decline in performance from Task A to Task B, the loss was much less than that of lows in ULA groups.

In summary, high-ability students performed better after learning individually or in MA groups than after learning in UA groups. For medium-ability students the order from best to worst conditions was UA grouping, individual learning, MA grouping. For low-ability students the order was MA grouping, individual learning, UA grouping.

Reliability of Standings in Individual and Group Conditions

This section examines reliability of scores from task to task. For the analysis all groups were pooled and individual scores were analyzed.

Reliability in the Group Condition

In Part I of the study,Tasks B and C provide some information on the reliability of learning in the group condition. Because different tasks were used in the group condition, stability of rank ordering, rather than absolute magnitude, is assessed.

Table 7 gives values of Kendall's tau among immediate and delayed tests for individuals in UA and in MA groups. For students who had learned in UA groups, rank order performance on immediate tests was more stable across tasks in the group condition than from individual task to group task. Students' delayed performance was fairly consistent from one task to another, regardless of condition. For those who had learned in MA groups, performance on immediate and delayed tests was no more consistent across tasks in the group condition than from individual to group task.

Reliability in the Individual Condition

The purpose of Part II of the study was to obtain information on reliability in the individual condition. This section examines stability of performance on Tasks A and B in Part II (individual condition), and compares that result to stability across Tasks A and B in Part I (individual condition to group condition). For the analysis, groups were pooled and individual scores analyzed. Table 8 gives nonparametric regression coefficients and values of tau relating the immediate test

Table 7

Kendall's Tau among Immediate Tests and among Delayed Tests

(All values are calculated from individual scores)

	Uniform-Ability			Mixed-Ability		
		Tau with			Tau with	
Task	SD Task	Task B	Task C	SD Task	Task B	Task C
Immediate test with immediate test						
Task A	2.7	.31	.27	4.9	.36	.20
Task B	5.4		.75	5.2		.14
Task C	4.0			4.1		
Delayed test with delayed test						
Task A	5.6	.43	.55	5.8	.57	.44
Task B	8.5		.47	8.2		.34
Task C	8.3			6.7		

Table 8

Nonparametric Regression and Correlation Coefficients Relating Task B to Task A (Immediate Tests)

(All values are calculated from individual scores)

	SD Task A	β^{*a}	Tau
Part II (Task A, Task B: Individual condition)			
All individuals pooled (N = 18)	3.0	.00	.24
Part II (Task A: Individual condition) (Task B: Group condition)			
All individuals pooled (N = 48)	3.9	.24	.34
Individuals in uniform-ability groups (N=28)	2.7	.08	.31
Individuals in mixed-ability groups (N=20)	4.9	.38	.36

[a] Procedures for estimating nonparametric regression coefficient β^* are presented in Appendix G.

on Task B to that on Task A. Regression coefficients are more meaningful than tau when standard deviations of the predictor variable (here, Task A) vary across samples. For individuals pooled within Part I and within Part II, immediate performance was somewhat less stable across tasks in the individual condition (Part II) than from individual to group condition (Part I). Immediate performance from Task A to Task B in Part I was more stable among individuals in MA groups than in UA groups.

Prediction of Delayed Test Performance from Immediate Test Performance

This section examines the relation of delayed to immediate tests in a task. The relation of delayed to immediate test in Task A (individual condition) is compared to that in Tasks B and C (group condition). As explained in Chapter III, the individual score is inappropriate as the unit of analysis in Tasks B and C. To use the same unit of analysis, all analyses in this section were carried out using group means.

As can be seen in Table 9, the regression coefficients predicting delayed test from immediate test were much the same in individual and group conditions. Coefficients predicting delayed test performance from immediate test performance (Table 10) were much the same in UA and MA groups for corresponding conditions.

Task C in MA groups was an exception, the sample regression coefficient being negative. MA groups that learned well initially remembered less of Task C than MA groups that learned poorly initially. With so few groups entering the analysis, however, there is great uncertainty in the results.

The regression coefficients among UA groups were greater than those among MA groups. UA groups that performed well on the immediate tests performed better on delayed tests than did MA groups that performed well on the immediate tests. Because this result appears in both individual and group conditions, it is not a consequence of the type of grouping. Again, with so few cases entering the analysis, sampling error may be responsible for the result.

Table 9

Nonparametric Correlation and Regression Coefficients Relating Delayed Tests to Immediate Tests

(All values are calculated from group means)

Condition and Task	Tau[a]	$\beta*$[b]	(β_L*, β_U*)[b]
Individual condition (N = 12)			
Task A	.48	1.10	(.08, 1.79)
Group condition (N = 12)			
Task B	.38	1.00	(-.70, 2.00)
Task C	.41	1.61	(-.33, 3.14)

[a] Kendall's tau.

[b] Procedures for estimating nonparametric regression coefficient $\beta*$ and confidence interval $(\beta*_L, \beta*_U)$ are presented in Appendix G.

Table 10

Nonparametric Regression Coefficients Relating Delayed Tests to Immediate Tests in Uniform-Ability and Mixed-Ability Groups

(All values are calculated from group means)

	Uniform-Ability (7 groups)		Mixed-Ability (5 groups)	
Condition and Task	$\beta*$	$(\beta*_L, \beta*_U)$	$\beta*$	$(\beta*_L, \beta*_U)$
Individual condition				
Task A	1.38	(-7.08, 2.66)	.11	(-2.34, 1.66)
Group condition				
Task B	1.44	(.38, 4.06)	.43	(-2.35, 7.54)
Task C	1.44	(-3.33, 2.72)	-2.67	(-10.25, 4.58)

Prediction of Outcomes from G

This section examines the relation of outcomes to G. All analyses in this section were carried out using group means. Prediction of outcomes from G is examined first among UA and MA groups separately. For completeness, prediction from G for UA and MA groups pooled is presented second. Prediction among female and male groups separately is presented third.

Comparison of Prediction in Uniform-Ability and Mixed-Ability Groups

Table 11 presents nonparametric regression coefficients predicting outcomes from G in UA and MA groups. Interpreting the between-groups regression coefficients in MA groups requires caution. Among MA groups the variance of group means in ability was small. A small change in the mean of a MA group would change the regression coefficient greatly. Thus, the between-group regression coefficients of outcome on ability among MA groups were not reliable. The instability of the between-group regression coefficients is shown in very wide confidence intervals. Among UA groups, the variance of group means on ability was large; hence, the regression coefficients are more meaningful.

The regression coefficients relating immediate test performance to G were much the same in UA and MA groups. The regression coefficients relating delayed test performance to G were inconsistent. In the individual condition, where all students worked singly and experienced the identical experimental procedure, the regression coefficient was greater among UA groups than among MA groups. In Task B (group condition) the same result appeared. In Task C (group condition) the regression coefficient was greater among MA groups.

The regression coefficients for delayed tests were greater in the UA and MA group conditions than in the individual condition. This is an Aptitude x Treatment Interaction effect in the sample. Groups above the median on ability did best on delayed tests in the group condition, whereas groups below the median performed better on delayed tests in the individual condition. Consistent with the values of the regression coefficients relating delayed performance to G, the confidence intervals in the group condition had higher upper bounds than those in the individual condition.

Table 11

Nonparametric Regression Coefficients Relating Tests to G for Uniform-Ability and Mixed-Ability Groups

(All values are calculated from group means)

	Uniform-Ability (7 groups)		Mixed-Ability (5 groups)	
Condition, Task, and Test	β^*	(β^*_L, β^*_U)	β^*	(β^*_L, β^*_U)
Individual Condition				
Task A				
Immed. test	.33	(-.06, 1.90)	.00	(-3.98, 8.44)
Delay. test	2.32	(1.58, 3.18)	.28	(-10.94, 4.30)
Group Condition				
Task B				
Immed. test	.59	(-1.13, 3.14)	.52	(-60.10, 30.33)
Delay. test	2.47	(-1.92, 5.59)	-1.07	(-60.10, 30.88)
Task C				
Immed. test	.00	(- .40, 1.74)	-.25	(-15.25, 10.22)
Delay. test	3.07	(2.15, 4.97)	4.95	(-40.60, 20.01)

The result of larger regression coefficients for delayed tests than for immediate tests is consistent with the large score declines of less able students. This result is equally strong in individual and group conditions.

Comparison of Prediction in Individual and Group Conditions

As seen in the previous section, regressions predicting outcomes from G among MA groups were not entirely meaningful. The analysis pooling UA and MA groups, therefore, is not entirely meaningful.

As can be seen in Table 12, the regression coefficients relating immediate tests to G were much the same in the individual and group conditions. Although the regression coefficient for the immediate test in Task C was somewhat lower, the 95 percent confidence interval around that coefficient was similar to those around other coefficients.

Comparison of Prediction among Female Groups and Male Groups

As shown in Table 13, the regression coefficients relating immediate tests to G were greater among male groups than among female groups. The differences between female and male groups were greater in the group condition than in the individual condition. The standard deviations of G were much the same among female groups and male groups: 1.52 and 1.70, respectively. In both individual and group conditions, higher-ability male groups performed better on the immediate tests than higher-ability female groups; lower-ability female groups outperformed lower-ability male groups.

When performance in the individual and group conditions was compared within sex a new result appeared. The regression coefficients relating immediate test performance to G were greater in the group condition than in the individual condition among male groups, and somewhat less in the group condition than in the individual condition among female groups. Higher-ability male groups performed better on immediate tests after students learned in groups than when members learned singly. Lower-ability male groups did better after members learned in interacting groups. No such trend appeared among female groups.

Consistent with earlier analyses, regression coefficients of delayed tests on G were generally higher than those of immediate tests on G. Differences in regression coefficients predicting delayed tests from G between female and male groups were inconsistent.

Table 12

Nonparametric Correlation and Regression
Coefficients Relating Tests to G
(All values are calculated from group means)

Condition, Task, and Test	Tau	β^*	(β^*_L, β^*_U)
Individual condition			
Task A (Part I; 12 groups)			
Immed. test	.46	1.37	(.00, 2.14)
Delay. test	.78	2.30	(1.60 2.91)
Task A (Part II; 5 groups)			
Immed. test	.80	1.64	(- .18, 3.74)
Task B (Part II; 5 groups)			
Immed. test	.60	1.07	(-1.63, 3.79)
Group condition			
Task B (Part I; 12 groups)			
Immed. test	.43	1.42	(- .10, 3.01)
Delay. test	.38	2.82	(-1.32, 5.19)
Task C (Part I; 12 groups)			
Immed. test	.54	.86	(.00, 2.78)
Delay. test	.69	3.11	(1.59, 4.94)

Table 13

Medians and Nonparametric Regression Coefficients Relating Tests to G for Females and Males

(All values are calculated from group means)

Condition, Task, and Test	Female (6 groups)			Male (6 groups)		
	Mdn	β^*	(β^*_L, β^*_U)	Mdn	β^*	(β^*_L, β^*_U)
Indiv. condition						
Task A						
Immed. test	18.4	.82	(-2.47, 2.23)	16.4	1.61	(.78, 3.41)
Delay. test	13.4	2.13	(.95, 3.42)	14.9	2.42	(1.61, 3.41)
Group condition						
Task B						
Immed. test	17.6	.79	(- .68, 1.84)	14.4	3.74	(- .13, 6.04)
Delay. test	13.2	3.26	(-3.22, 6.89)	7.0	1.90	(-2.24, 8.39)
Task C						
Immed. test	18.0	.53	(- .50, 1.42)	18.1	2.56	(.00, 2.84)
Delay. test	14.0	2.80	(.00, 4.94)	11.2	4.22	(1.51, 6.58)

CHAPTER V

GROUP PROCESS RESULTS

A major purpose of the present study was to determine how group process accounted for any difference between learning in individual and in group settings, and between learning in uniform-ability (UA) and mixed-ability (MA) groups. This chapter examines verbal interaction among group members: the roles played by high-ability, low-ability, and medium-ability students, in that order, with particular attention to differences between UA and MA groups.

Major Group Process Variables

The scheme for examining verbal behavior evolved as the study progressed. During a pilot experiment, transcripts of problem-practice sessions had been made from audio recordings. Twelve categories were formed to code verbal interaction among group members. Every utterance was coded. The size of an utterance ranged from a one-word exclamation ("Oh") to a lengthy explanation of how to solve a problem. A thirteenth category was added to code non-task-related verbal interaction (e.g., a discussion of surfing). Table 14 gives the name and definition of each category of verbal interaction on the instrument.

In the study all problem-practice sessions were coded using the thirteen-category system. Not only was verbal interaction coded, but the speaker and target of every utterance were noted. If comments were not directed at a particular member, the target was labeled "group". Participation indices were formed by dividing the number of utterances made by a student by the total for all students in the group.

The only category of the thirteen-category system that related to achievement was "Explains." It became evident that molar categories of group process seemed to be more highly related to achievement than the molecular thirteen-category system. Even the original definition of "Explains" was restrictive. That category was enlarged after coding of the thirteen categories to include any member asking another if he or she understood how to solve a problem.

Table 14

Preliminary Coding Instrument

Category Name	Category Description
Proposes idea, gives information	A student suggests what to do, provides an idea, gives information, carries out a calculation.
Explains	A student explains to another how to do something, clarifies something already said or done.
Criticizes	A student finds fault in another student's contribution, detects an error in another member's idea, explanation, or calculation.
Evaluates positively	A student agrees with a suggestion, statement, proposal, saying the idea is good, correct, will help solve the problem.
Detects/corrects omission	A student detects an omission in another member's solution and fills in the information (includes explicit mention of omission).
Shows comprehension, understanding, insight	A student expresses comprehension, understanding, insight, as a result of something another student said or did.
Requests clarification, explanation	A student asks for clarification or an explanation.
Requests fill-in of memory	A student admits having forgotten some information and asks for information.
Gives support	A student praises, rewards, compliments, gives approval, encourages, gives credit, shows enthusiasm for participation by other students.
Requests information	A student asks for information, definitions.
Proposes strategy	A student suggests how to set up a problem without actually solving it.
Negative interaction	A student shows antagonism, mocks another.
Other	A student says something that cannot be coded in the above categories, including non-task-related interaction.

Four molar categories seemed to relate to a student's success in learning. The following questions and subquestions describe the relevant behavior:

1. Did the student actively teach fellow members? Did the student explain how to solve a problem, and/or ask fellow members whether they understood how to solve a problem?
2. Did the student solicit and/or receive teaching behavior from fellow members? Did the student ask questions of teammates, admit confusion about the procedure for solving the problem, or receive explanations?
3. Did the student's questions or suggestions receive recognition?
4. Did the student discourage teammates from taking time to explain or discuss how to solve a problem, encouraging them instead to obtain answers as quickly as possible?

In the modified coding system not all verbal interaction was coded. Dichotomous scoring was used. Students explained or did not explain, were or were not targets of explanations, were or were not ignored when they tried to participate, and did or did not discourage teammates from taking time to explain. For most students, scoring was straightforward. For example, a student either offered several explanations or offered none.

The following is a preview of conclusions that will be developed. In general, students who actively taught fellow members, particularly by explaining to others, learned and remembered more than students of similar ability who explained little. Students who solicited and received explanations did better on the immediate test than students of similar ability who did not. Students who received explanations tended not to retain what they had learned, however. In groups in which a member discouraged teammates from asking questions or explaining, with the intent of getting to solutions faster, performance by lower ability students suffered. Finally, students whose suggestions, questions, and admissions of confusion were ignored by other group members performed worse than students of similar ability who were not ignored.

Performance by students within a group, then, depended both on their ability and their social interactions. Group process in each group will be examined next to try to account for each student's performance.

High-Ability Students in Uniform-Ability and Mixed-Ability Groups

It will be recalled that high-ability students in every condition performed well on the immediate tests. In the two uniform-high-ability

(UHA) groups, however, retention was poor in Task B (group condition). Five out of eight students forgot how to solve Task B. In MA groups three out of the five high-ability students performed Task B perfectly one week after learning. The finding is best understood by describing the active leadership role the high-ability member played in MA groups. Such behavior was less frequent in UHA groups.

In most of the MA groups, particularly in female groups, the high-ability member behaved like a teacher, for example, explaining how to solve a problem. The high-ability member often asked questions of less able members to ascertain whether they understood how to solve the problem. The high-ability member usually provided most of the explanations offered in an MA group, particularly the ones directed toward the least able member. In most groups, the high-ability member responded to another student's question or to a comment expressing confusion by explaining the problem. The most-able member sometimes led the others through part or all of a problem, explaining each step. Sometimes the most-able member served as a resource for less-able members. Typically, the high-ability member performed most of the calculations. Some of them checked the work of other members to detect confusion and correct errors.

The following are illustrative verbal exchanges between high- and low-ability members in MA groups. These excerpts show the high-ability member responding to the low-ability member's question with an explanation, or trying to determine whether the low-ability member understood calculations done by others.

1.	Low-ability student:	How do you get this (4n-3)?
	High-ability student:	This is the first number. This is the last number (a+(n-1)d). We just found that out here. (points) We just found the last number by going (a) plus (n-1) times (d). "d" is the distance between layers. So the first number plus the second times the total number divided by 2 gives you this . . . The last number's going to be the first number, a, plus n-1, which is the total number of rows you're going to have times the distance between each number: 1, 5, 9 . . .
2.	High-ability student:	Does that make sense so far, Kim?
	Low-ability student:	Mmm . . . sort of . . .

High-ability student: We have to make sure it makes sense. If you have a triangle like that and another like that, you will have four dots on one side. Right? "n" is the number of dots on that side. 4 minus 1 is going to be equal to the number of triangles. . . . You have that one, this one, and that one, three. Now, it works the same for hexagons. . . See this thing right here? That's a triangle. Then there is this thing which is a triangle. And then that one. That'll work for anything . . . anytime you put figures together into an array of dots.

Low-ability student: OK. I get it!

3. Low-ability student: Isn't the last number you're going to have n?

High-ability student: The last number isn't n. "n" is the number of dots on a side. And what we're finding here is the number in the whole figure when we have n on a side.

Low-ability student: OK

High-ability student: Wait. Do you understand how to do it? You write it . . .

That the high-ability member is playing the role of "teacher" is obvious in these excerpts.

Every high-ability student in MA groups who exhibited teaching behavior in Task B learned and retained Task B. The high-ability students in MA groups who did not explain to less-able members did not remember the task well.

In UHA groups fewer explanations were given, presumably because most members seemed to understand what to do. After brief explanations, members who had expressed confusion said that they understood. All members worked through computations on most or all parts of the problem. Much of the session was spent calculating--little time was spent explaining.

Although little time was spent in explaining how to solve problems in the UHA groups, some members did offer explanations. Only the students who explained some aspect of Task B remembered how to solve Task B. The students who had not explained part of the problem remembered little of Task B.

High-ability students played the same role in Tasks B and C. High-ability students who actively taught Task B also taught Task C. Those who did not explain any part of Task B did not explain Task C. Every high-ability student showed excellent performance in Task C on the immediate and delayed tests. Because the variance in test scores was very small, an active teaching role could not be reliably associated with better performance.

Table 15 shows the performance of high-ability students on immediate and delayed tests on Tasks B and C (group condition) according to whether they played active teaching roles in their groups. Also presented as a comparison with achievement after group learning are mean G scores and mean scores on the immediate and delayed tests on Task A (individual condition). Whether students retained most of Task B was associated with whether they had actively taught.

That some high-ability students in MA groups actively taught did not seem to be a symptom of greater ability or greater understanding of similar tasks. Students who explained Task B in MA groups had about the same ability as those who did not. Students who taught Task B had learned and remembered Task A (individual condition) no better than students who did not explain Task B. In UHA groups, however, an active teaching role was associated with greater ability. An active teaching role was not associated with superior performance on Task A (individual condition). Early in a problem-practice session, most high-ability students in MA and UHA groups made mistakes while explaining. Sometimes the high-ability student detected and corrected the errors before another student intervened. Often, however, another student detected the error. That high-ability students made mistakes indicates that willingness to teach is not a *consequence* of excellent understanding.

A crucial variable associated with whether high-ability students retained what they learned was whether they explained to other group members how to solve the problem. In MA groups, there was ample occasion for the high-ability members to "teach" less able members. The high-ability members of those groups subsequently remembered how to solve the problem. Those who had explained little to their fellow members did not remember. In UHA groups, students had less opportunity to explain because most members learned quickly. But members who offered even one explanation retained all of what they learned. Members who did not explain did not remember. Because the few students in UHA groups who did explain had higher ability than those who did not explain, it is not clear whether explaining in UHA groups was a symptom or a cause of understanding the task.

Table 15

Means of High-Ability Students on Ability and Outcomes According to their Roles in the Group

(All values are calculated from individual scores)

			Task A		Task B		Task C	
Actively Taught	n	G	Immed. Test	Delay. Test	Immed. Test	Delay. Test	Immed. Test	Delay. Test
Mixed-ability groups								
Did	3	2.4	20.0	17.3	20.0	18.7	18.3	19.0
Did not	2	2.8	19.5	19.0	19.0	14.0	19.0	18.5
Uniform-ability groups								
Did	3	3.1	20.0	19.7	20.0	19.3	20.0	19.7
Did not	5	2.3	19.6	19.2	17.4	5.0	18.8	18.6

Low Ability Students in Uniform-Ability and Mixed-Ability Groups

The major finding for low-ability students from the previous chapter is the following. Low-ability students did their poorest after learning in uniform-low-ability (ULA) groups and did their best after learning in MA groups. Although working with more-able students helped their immediate performance, few low-ability students retained what they had learned.

Two variables seemed to be associated with better performance by a low-ability student after learning in the group condition than after learning singly. The primary variable was whether the student was a target of coherent explanations. A less potent variable was whether the low-ability student attempted to explain.

In three out of five MA groups, the high-ability member tried to teach the low-ability member how to solve the problems. In a fourth MA group, the low-ability member was taught by a medium-ability student. Whenever the low-ability member asked a question or admitted confusion, the high or medium-ability "teacher" readily supplied an explanation. The "teacher" usually continued explaining until the low ability member expressed understanding. Low-ability students in these groups performed better on immediate tests after learning in the group condition than after learning in the individual condition. On delayed tests the results were inconsistent.

In the fifth MA group the low-ability student did little better after group learning than after learning in the individual condition. In this group no high or medium-ability member tried to teach the low-ability student. One medium-ability member discouraged other group members from taking time to explain to the low-ability student or answer his questions. Subsequently, the low-ability member was usually ignored and was rarely given an explanation when he did ask for one. The low-ability member did not learn how to solve much of either task in the group condition. The low-ability member of this group remarked after the experiment that he felt inhibited from asking questions, even though he did not understand how to solve the problems.

In MA groups, then, low-ability members who were the target of extensive explanations learned how to solve the problem, even if they did not always retain that learning. The low-ability student who did not receive explanations did not learn the tasks.

There were two ULA groups. In one, two members explained to the other members. The explanations were usually incomplete and unclear; no member seemed to understand the explanations. The student who received comparatively few of the explanations did poorly. The student who received most of the explanations did even worse. Thus, receiving explanations was not associated with better performance. The members who offered the explanations did well on the immediate tests, but no better than they had after learning in the individual condition. On the delayed tests all members in the group performed poorly.

In the second ULA group, only one member gave any explanations. His explanations, usually incomplete and often incorrect, were not directed at any specific member. The other members rarely understood his explanations and continued to make mistakes. The member who offered explanations performed well on one immediate test, but did poorly on the delayed tests. The other members performed poorly on all immedate and delayed tests.

In ULA groups, then, the group condition had a disastrous effect for many members. Except for one student on one test, every student performed better on both tests after learning in the individual condition than after learning in the group conditions. Students who offered explanations showed adequate immediate performance; students who received explanations showed less than adequate performance; students who did neither showed very poor performance.

Table 16 shows the performance of low-ability students on all tasks according to whether they received or offered explanations. Only students who received explanations from high or medium-ability students in MA groups performed better after learning in the group condition than after learning singly. Although lows in MA groups had lower ability than those in ULA groups, their performance on the tests on Task C was at least as good as that of the most-able students in ULA groups.

In summary, low-ability students in MA groups benefited from the extensive explanations by more-able members. Students in ULA groups did not benefit much from explanations presumably because the explanations were incomplete or incorrect. Students in ULA groups who offered explanations did better than those who received the explanations or were passive, but did worse than in the individual condition.

Table 16

Means of Low-Ability Students in Ability and Outcomes According to their Roles in the Group

(All values are calculated from individual scores)

Received or Offered Explanations	n	G	Task A Immed. Test	Task A Delay. Test	Task B Immed. Test	Task B Delay. Test	Task C Immed. Test	Task C Delay. Test
Mixed-ability groups								
Received	4	-3.8	11.8	6.2	14.2	3.0	19.0	11.5
Neither	1	-4.7	5.0	1.0	10.0	5.0	4.0	3.0
Uniform-ability groups								
Received	2	-2.3	20.0	10.0	11.5	1.5	15.0	7.5
Offered	3	-2.0	18.0	10.0	16.0	2.3	19.3	3.7
Neither	3	-2.5	12.3	6.0	4.7	.3	8.3	.7

Medium-Ability Students in Uniform-Ability and Mixed-Ability Groups

In the previous chapter it was seen that medium-ability students learned and remembered as much after learning in UMA groups as they did after learning singly. Most medium-ability students in MA groups, however, learned and remembered less than in the individual condition.

In MA groups medium-ability students played the role of the typical high-ability student in MA groups, that of the typical low-ability student in MA groups, or they were ignored. Medium-ability students who actively taught other members showed excellent performance on all tests. These students (all of high medium ability) worked through as many or more of the computations as did high-ability students. They offered many explanations, and asked questions of less-able members to ascertain whether they understood how to solve the problems.

Other medium-ability students in MA groups asked questions and persisted until the high-ability member or another medium-ability member offered an explanation. These students did better on both immediate tests after learning in the group condition than after learning in the individual condition. They did better on one delayed test after learning in the group condition than after learning in the individual condition. On the other delayed test they did worse.

In two of the five MA groups, most of the interaction was between high and low-ability members. In a third MA group, the interaction was mainly between a medium-ability member and the low-ability member. In these three groups one or both medium-ability students were left out. Even when they asked for help, or said that they were confused, other members rarely offered any explanations. Every medium-ability student who was ignored showed a decline from his performance in the individual condition. Medium-ability members who had been ignored tended to pay less attention to the task. If another member asked whether they understood how to solve a problem, they responded affirmatively, but continued to make mistakes.

Thus, the medium-ability students who did well in MA groups interacted in group problem-solving. Those who explained showed excellent immediate and delayed performance. Those who received explanations showed better immediate performance and, on one task, better delayed performance than after learning in the individual condition. The medium-ability students whose performance suffered were usually those who had been ignored by other members of the group.

Apparently MA groups could help only one member of the group. When several members of the group did not understand how to solve the problem, the group concentrated its attention on the least able member. Medium-ability members had to be aggressive in soliciting explanations, or they were ignored.

In UMA groups members participated evenly--no member was ignored. Everyone interacted in solving problems. Characteristic of these groups was a supportive atmosphere in which all members explained some part of the procedures, and made certain that other members understood how to solve the problems. Although more time was spent in explaining than in other groups, no member expressed impatience. In most of the groups a particular member explained every step in the problem-solving procedure.

Nearly every member in these groups achieved perfect or near perfect scores on the immediate tests. They performed about as well on delayed tests after learning in the group condition as they had after learning in the individual condition. In UMA groups, then, balanced participation among group members was associated with excellent learning. In groups in which a member explained or summarized the entire procedure, every member showed excellent retention as well as excellent immediate learning.

Table 17 summarizes the results according to whether medium-ability students in MA groups offered or received explanations, or were ignored. Those who offered explanations were usually of higher ability and performed better on Task A (individual condition) than other medium-ability students in mixed-ability groups. Being ignored in a MA group was not, however, a symptom of lower ability or less understanding of the tasks in general. Those who were ignored had slightly higher ability, and performed better on Task A (individual condition) than those who received explanations. Students in UMA groups could not be classified as to role. In general, they performed better on the immediate tests and almost as well on the delayed tests after learning in UMA groups as after learning in the individual condition.

Table 17

Means of Medium-Ability Students on Ability and Outcomes According to their Roles in the Group

(All values are calculated from individual scores)

Received or Offered Explanations or Ignored	n	G	Task A		Task B		Task C	
			Immed. Test	Delay. Test	Immed. Test	Delay. Test	Immed. Test	Delay. Test
Mixed-ability groups								
Offered	3	1.2	19.7	19.0	20.0	20.0	19.3	19.7
Received	3	-.8	15.0	12.3	18.3	15.7	17.7	6.3
Ignored	4	-.7	17.0	13.2	9.8	2.8	16.0	9.8
Uniform-ability groups	12	.8	19.1	16.4	19.9	15.1	20.0	14.6

Questionnaire on Group versus Individual Settings

During the last session of the experiment students completed a questionnaire about their experiences in the individual and group settings. In this section their perceptions of the learning settings are compared with the experimenter's observations of group process.

Procedure of the Analysis

The students' responses to items on the questionnaire were entered into a cluster analysis. Items were clustered using the correlations between pairs of items. In the clustering procedure the distance between two clusters of items was the longest distance from an item in the first cluster to an item in the second cluster.

Although the cluster analysis produced six clusters of items only two were related to the observations of group process. One cluster contained items that defined the degree to which the student perceived the group as a teaching agent. This cluster was called TEACHING. The other cluster contained items that related to the students' perceived productivity in the group condition compared to that in the individual condition. The second cluster was called PRODUCTIVITY. Table 18 gives the items that appeared in each cluster.

Students' scores on a cluster were the means of their responses on the items in the cluster. The scale of each item ranged from 1 to 5. Thus, both cluster scores could have the same range. A score of 5 on TEACHING indicated that the student said that the group acted as a teaching agent; a score of 1 indicated that the group did not help the student learn. A score of 5 on PRODUCTIVITY indicated that the student perceived that he or she was more productive in the group'condition; a score of 1 indicated greater productivity in the individual condition. The correlation between TEACHING and PRODUCTIVITY for all cases pooled was .75. Because the indices had different means, each index is reported and interpreted.

Results of the Analysis

The classifications of students according to roles in the previous section were combined to form four categories. In the first category were students who tried to teach teammates. In the second category were students who received explanation from other group members. In the third

Table 18

Items in Two Clusters from the Questionnaire
on Group versus Individual Settings

TEACHING
The group detected and corrected errors in my work that I wouldn't have caught myself.
The group helped me to remember things I couldn't remember by myself.
The other members' explanations helped me to understand the material.
I understood the material better when I worked in the group.
I learned the material better when I worked in the group than when I worked by myself.
PRODUCTIVITY
I had more ideas in the group than when I worked by myself.
When I worked in the group I got more done than when I worked by myself.
I was more motivated to learn when I worked in the group than when I worked by myself.
I was more confident that I could learn the material when I worked in the group than when I worked by myself.
I learned more when I worked in the group than when I worked my myself.
In general I prefer to work in a group rather than to work by myself.

category were students who interacted in solving problems, but who were not predominantly teachers or targets of explanations. In the fourth category were students who did not interact much in solving problems. Included in the fourth category were medium ability students who had been ignored in MA groups.

Table 19 gives the mean cluster score in each category for all relevant ability levels. Students who received explanations perceived the group as helping them learn how to solve problems better than they were able to learn in the individual condition. Except for those in ULA groups, they also perceived themselves as more productive in the group condition. Students who explained to others (except for highs in UHA groups) perceived themselves as more productive in the individual condition. Active participants who were neither predominantly teachers nor recipients of explanations tended to say that the group helped them learn, but they thought they were equally productive in the individual and group conditions. Passive members (except for those in ULA groups) perceived the group as helping them learn. Passive members were inconsistent in their perceptions of productivity.

The results of the questionnaire show some agreement between students' perceptions of group process and the experimenter's observations of group process. Most important, students who received explanations indicated that the group helped them understand the tasks better than when they worked by themselves.

Other Personality and Ability Variables

Prior to this study, all students had taken over 25 ability tests and the Strong-Campbell Interest Inventory (SCII). In this section, roles in group process are related to scales on the SCII, and to ability factors more specific than G.

SCII Scales

The Special Scales of the SCII, formerly called the Nonoccupational Scales, were thought possibly to be correlates of roles in group process. The first scale, Academic Orientation (AOR), was designed to measure persistence in an academic setting. According to Campbell, high scores on AOR are earned by people who intend to become well educated. The second scale, Introversion-Extroversion (IE), is supposed to measure a person's interest in working alone or with other people. People who would prefer to work alone obtain high scores on IE.

Table 19

Mean Scores on Clusters in Questionnaire According to Students' Roles in Groups

Role in Group	Ability Level and Type of Grouping	n	Teaching	Productivity
Teacher	Highs in MA groups	3	2.4	1.6
	Highs in UHA groups	3	3.6	3.3
	Mediums in MA groups	3	4.1	2.7
	Lows in ULA groups	3	3.0	2.7
	Cases pooled	12	3.3	2.6
Target of explanations	Mediums in MA groups	3	4.2	3.9
	Lows in MA groups	4	4.2	3.3
	Lows in ULA groups	2	4.0	2.9
	Cases pooled	9	4.2	3.4
Other active participant	Mediums in UMA groups	12	3.6	3.2
Passive member	Highs in MA groups	2	3.0	2.7
	Highs in UHA groups	5	3.2	2.4
	Mediums in MA groups	4	4.5	3.2
	Lows in MA groups	1	4.6	4.8
	Lows in ULA groups	3	2.6	2.6
	Cases pooled	15	3.5	2.8

Table 20 gives the mean scores on AOR and IE for each role within ability level. (Within this sample AOR and IE were correlated -.15.) Active members (teachers, active participants, and targets of explanations) were more academically oriented than passive members at every ability level. Passive members were more introverted than active members among high-ability and low-ability students, but not among medium-ability students.

As reported earlier in this chapter, medium-ability students in MA groups who received explanations (targets of explanations) had the same ability as those who were ignored (passive members). Neither SCII scale clearly distinguished between passive and target medium-ability students. AOR showed little difference between passive and target mediums. IE showed a trend in the direction opposite to that at other ability levels; passive medium-ability students were less introverted than target medium-ability students.

Ability Factors

The factor analysis that produced factors G_f and G_c used to select students and assign them to groups produced three other factors: Memory Span (M), Perceptual Speed (PS), and Closure Speed (CS). (All ability factors were uncorrelated.) Mean scores on G_f, G_c, and M for each role within ability level appear in Table 20. (PS and CS yielded no consistent results, hence, they were not included in Table 20.) Active members (teachers, active participants, and targets of explanations) had greater scholastic ability (G_c) than passive members among high-ability and medium-ability students, not among low-ability students. Active members had greater nonverbal spatial ability (G_f) and greater memory span (M) than passive members at all ability levels (except for medium-ability teachers on M). None of the ability factors distinguished between passive and target medium-ability students, so the clue to what distinguishes these students lies outside the variables examined here.

Table 21 gives Pearson correlation coefficients between SCII scales and ability factors. Academic Orientation was independent of Memory Span, but was not independent of G_f and G_c. Introversion-Extroversion was independent of the ability factors. The following variables, then, related to a student's role in group process: a composite of Academic Orientation, G_f and G_c, Memory Span, and Introversion-Extroversion.

Table 20

Mean Scores on SCII Scales and Ability Factors According to Ability Level and Role in Group

Ability Level	Role in Group	n	SCII		Ability		
			AOR^a	IE^a	G_c^a	G_f^a	M^a
High	Teacher	6	49	53	.94	.84	.31
	Passive member	7	47	64	.60	.71	-.25
Medium	Teacher	3	41	55	.54	.81	-.67
	Active participant	12	41	53	.09	.40	.52
	Target of explanations	3	39	53	.28	-.19	.13
	Passive member	4	34	47	.38	-.32	.08
Low	Teacher	3	41	46	-.07	-.57	.38
	Target of explanations	6	27	52	-.58	-.64	-.15
	Passive	4	20	65	-.65	-.60	-1.16

[a] The standard deviations of the sample of 48 subjects on AOR, IE, G_c, G_f, and M are 14, 11, .78, .78, .89.

Table 21

Correlations of SCII Scales with Ability Factors

SCII Scales	Ability Factors		
	G_f	G_c	M
AOR	.45	.45	.02
IE	.21	.03	-.01

CHAPTER VI

SUMMARY AND CONCLUSIONS

This study compared learning in individual and group settings, and attempted to explain differences as a function of the characteristics of student, group, and group process. In this final chapter the problem and method of the present research and its conclusions are summarized. The results of the present study are related to previous findings, and implications for the teacher in a classroom and for further research are discussed.

Summary of the Present Research

The Research Problem

Over the past half century psychologists and educators have examined performance in individual and group settings. But few studies compared learning by an individual working singly, not permitted to interact with other students, and that of an individual working in an interacting group. The few studies that compared learning in controlled individual and group settings produced inconsistent results. These studies did not observe the same student learning in both settings. More important, the investigator did not observe group process.

The present study compared learning by students working singly with that of the same students working in interacting groups. Students learned how to perform certain mathematical analyses. Every variable examined in the literature on learning in small groups was manipulated or controlled in the present study: instructions for interaction among group members, group composition on ability, subject matter, and group size. Group members were encouraged to help each other learn in four-person groups of uniform ability (high, medium, or low ability), or in groups of mixed ability. Group process was examined to account for changes in learning from condition to condition.

Design and Procedure

Students in Part I of the study performed three tasks, the first task in the individual condition and the others in the group condition. The data on the last two tasks yielded reliability information on individual differences in learning in the group condition. Each task was learned in a three-phase session. In the first phase, training, students received instruction on the components of the task. During the second phase, problem-practice, students learned how to solve complex problems which incorporated the components learned during training. In the third phase, testing, students were tested on complex problems similar to those solved during problem-practice.

Students were assigned to uniform sex groups of four. Twelve groups (six of each sex) participated in Part I. Six groups were homogeneous, all members having high, medium, or low ability. Each of the six mixed-ability groups had one high-ability student, two medium-ability students, and one low-ability student. Ability levels were defined comparatively; the low-ability students had IQ's near or above 100.

Students in Part II of the study worked on two tasks, both in the individual condition. The data from the 18 subjects in Part II yielded reliability information on learning in the individual condition.

The tasks were mathematical reasoning problems. The task for the first session dealt with mathematical probability. The task for the second session was based on polygonal numbers. The task for the third session dealt with positive and negative number bases.

Test Results

The performance of many students declined dramatically from immediate test to delayed test, in either mode of study. In the individual condition, the loss was exhibited mainly by lower-ability students; in the group condition, the performance of students at all ability levels declined. One session of practice was sufficient for many students to learn to solve the problems, but was not enough for them to consolidate what they had learned.

Statistics describing performance of the group as a whole in the individual condition did not differ from those in the group condition, except for a difference in the regression of delayed tests on ability. The regressions were not entirely meaningful, however, because they pooled uniform and mixed-ability groups.

Types of grouping interacted to some extent with condition of learning. For mixed-ability groups on immediate tests, the group condition was superior to the individual condition. For uniform-ability groups on immediate tests, the two conditions of study were equally effective. On delayed tests, however, average scores were higher after learning in the individual condition than after members learned in interacting groups. The regressions of delayed tests on ability in uniform-ability groups showed evidence of an ATI effect. On delayed tests, groups above the median on ability performed better after learning in the group condition than after learning in the individual condition. Groups below the median showed better delayed performance after learning in the individual condition than after learning in the group condition.

On immediate tests, higher-ability males performed better than higher-ability females, whereas lower-ability females performed better than lower-ability males. An ATI effect was found among males: the group setting was advantageous for higher-ability males and detrimental to lower-ability males.

In uniform-ability groups, immediate performance across tasks learned in the group condition was more stable than performance on one task in the individual condition and the other task learned in the group condition. In mixed-ability groups, immediate performance was no more reliable after group learning than after learning in different settings. Delayed performance of all students was fairly consistent from task to task, regardless of the learning condition.

Individual Differences within Groups in Process and Outcome

Ability level within groups interacted with type of grouping. Judging especially by delayed tests, high-ability students performed equally well after learning in mixed-ability groups or individually, and less well after learning in uniform-ability groups. For medium-ability students the order from best to worst conditions was uniform-ability grouping, individual learning, mixed-ability grouping. For low-ability students the order was mixed-ability grouping, individual learning, uniform-ability grouping.

These results were in part explained by the roles students played in group process. Whether a high-ability student assumed a teaching role in the group was associated with better retention. High-ability students in mixed-ability groups often explained to less-able members, whereas highs in uniform-ability groups rarely did so. Highs who actively taught in mixed-ability or in uniform-high-ability groups showed excellent delayed performance; those who did not teach were comparatively weak on delayed tests.

Low-ability students who received coherent explanations, as happened often in mixed-ability groups, performed better than those who did not. In a uniform-low-ability group, however, explanations did not appear to help the student who was the target. Explanations given by low-ability members were unclear and often incorrect. Indeed, low-ability students often confused each other. Hence, low-ability students in uniform-low ability groups were better off working singly.

Medium-ability students who actively interacted in solving problems benefited from group learning. In uniform-medium-ability groups all members worked through computations, explained, and received explanations. No member was more active than another, and no member assumed a particular role. In these groups, medium-ability students showed excellent performance, particularly on immediate tests. In mixed-ability groups those medium-ability students who did not play active teaching roles or aggressively ask for explanations were ignored. Subsequently, they performed worse than after individual learning. Those who actively taught did well on all tests. Those who received explanations did less well, but better than after individual learning.

Conclusions and Implications

"Is the group or individual condition superior?" is not the right question. A better question is "For which student is a certain kind of group environment superior to individual learning?" As in previous studies no main effects of group versus individual conditions of learning appeared here. But effects differed with the ability level of the students, and the group environment had conspicuous effects. Whether the group or the individual setting was advantageous for a student of a particular ability level depended upon the ability of others in the group and the student's role.

The results of group process in the present study provided evidence for a participation hypothesis: in general, group members who actively participated did better than those who did not actively participate, and did at least as well as after individual learning. Active participation includes offering and receiving explanations. Whether a group member actively participated seemed to be related to the student's rank on ability within the group and the range of ability in the group.

Other researchers obtained results consistent with the hypothesis described above, but they did not provide direct evidence. Klausmeier, Wiersma, and Harris (1963) advanced a participation hypothesis to explain a finding different from the results in the present study. In their study the individual condition was superior to the group condition. Klausmeier et al. hypothesized that active participation is an important variable; a student learning alone is by definition active whereas in a group some members may not participate. The results of the present study support their hypothesis. Their analysis of group data did not differentiate between students who participated and those who did not. It is therefore incomplete.

The large body of research on tutoring provides results consistent with the elaborated participation hypothesis of the present study. Most of the studies examined cross-age tutoring, but some studies investigated peer tutoring (e.g., Mollod, 1970; Gartner et al.,1971;C.C.Smith,1977). In nearly all studies tutors and tutees benefited, with tutors improving more than tutees. This result is analogous to that of a high-ability student explaining to a low-ability student in a mixed-ability group in the present study. In the tutorial situations tutors were instructed to explain to tutees, and tutees were expected to learn from their tutors. Thus, process variables observed to be important in the present study were manipulated in the tutorial studies. Although the investigators did not verify that tutors did in fact explain to their tutees, the results support the participation hypothesis.

A "teacher-learner" relationship was hypothesized by Amaria, Biran, and Leith (1969) to explain the results of their study. They did not manipulate group process, but observed variations among groups of various composition. In two-person groups, a mix of ability was better than all high or all low-ability pairs. Amaria et al. hypothesized that the high-ability member benefits from explaining to the other member and that the low-ability member profits from being the target of those explanations. Amaria et al. provided no direct evidence regarding the use of explanations.

A different process was suggested as a cause by Beane and Lemke (1971). In their study high-ability students learned more individually than in uniform-high-ability groups; low-ability students, however, learned more in uniform-low-ability groups than individually. Beane and Lemke suggested that high-ability students were able to develop individual strategies quickly. In their group condition members of the group had to agree on one strategy for solving the problem. When students worked on a transfer task after group training, the problem-solving strategy developed by the group interfered with the individual's strategy, Beane and Lemke suspected. To explain the results of low-ability students, Beane and Lemke suggested that most low-ability students did not develop individual strategies. During group training students developed one group strategy. The group strategy then became the individual's strategy for the final transfer task. Beane and Lemke presented no evidence relating to their explanation.

The present study had no data directly relevant to the Beane-Lemke interpretation, but their data can be interpreted as the present study was, by the roles group members played. Their concept attainment task was probably simple enough that high-ability students did not need to explain the concepts to teammates. Without explaining to others, high-ability students may not have attended to the task and may not have consolidated their learning. Low-ability students may have found the task simple enough to explain coherently to teammates. If low-ability students understood the explanations offered, explainers and targets of explanations would have benefited. In the present study no low-ability student provided coherent and complete explanations of the complex tasks.

The participation hypothesis of group process in the present study may explain many of the results in the studies reported. In view of the evidence for the influence of group process, comparing learning in individual and group conditions makes little psychological sense without disaggregating by ability levels and roles.

The results of the present study have clear implications for teaching practices in the classroom, especially for small group instruction. Teachers should be aware that students have specific roles in small groups. In the present study some students actively taught while others were targets of that teaching. Some students actively participated without assuming a particular role. Others did not actively interact; some were passive from the start, whereas others were ignored even when they tried to participate. Some roles were associated with good performance;

others were not. Thus the group environment was advantageous for some members and not for others.

When forming small groups in the classroom, teachers should know that a student's role in a group depends upon the ability level and composition of the group. At most ability levels in the present study, active roles led to better performance than passive roles. To encourage high-ability students to teach actively, those at high levels of ability might be assigned to groups containing low-ability students. Medium-ability students, however, might interact most and learn best in uniform-medium-ability groups.

Teachers should pay attention to group process. Merely assigning students to the most advantageous group environment is not enough. Processes of interaction may differ from group to group, even across groups with the same mix of ability levels. For example, in the present study, some mixed-ability groups suppressed explaining to less-able members, whereas others encouraged explaining. Teachers may have to monitor interaction in some groups to stop a member who tries to discourage others from explaining or who encourages the group to work fast to obtain answers.

Teachers may consider giving specific instructions to groups, encouraging members to help each other learn. As in the present study, incentives such as a high team score for good performance by all members may promote effective interaction and learning within a group.

Implications for further research are clear. Studying short-term learning in small groups is suggestive, but does not arrive at stable styles of interaction among group members. Interactive styles may change as students get to know fellow members. Longitudinal studies of small groups are needed to determine how students' roles in group process change over time. Personality and ability variables and characteristics of group members should be related to student outcomes.

This study is a first attempt to uncover student and group characteristics and group process that relates to a student's performance. The small size of the study limited the statistical significance of the results, but did not limit the importance of the relations between group process and performance.

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APPENDIX A

SAMPLE PRACTICE PROBLEM FOR TASK A

Suppose you play a gambling game at a Las Vegas Casino. In this game you have to do two things. First you have to spin a pointer on a spinner that has four colors: red, blue, yellow, and green. Each color is equally likely. (Assume that the pointer does not land on the boundary between colors.) Second you have to toss an honest six-sided die. You win $50 if the pointer lands on red or if the die comes up showing a 4. If anything else happens you don't win anything. What is the expected value of this game?

APPENDIX B

SAMPLE PRACTICE PROBLEM FOR TASK B

Find the formula for the nth hexagonal number.

APPENDIX C

SAMPLE PRACTICE PROBLEM FOR TASK C

You are on an interplanetary mission aboard the Starship Enterprise. The Enterprise is traveling to an outlying planetary system which was recently ravaged by a war among the five planets in the system. The war was fought by two sides: Omega I, Omega II, Omega III against Alpha I and Alpha II. Alpha I and Alpha II were severely beaten and now are in desperate financial straits. Your role is that of a Federation accountant and diplomat. Your mission is to collect money from Omega I, II, and III to give to Alpha I and Alpha II to help pay for damages.

Your accounting skills are needed because the monetary system of each planet is in a different base. You must first collect the money that each of the Omega planets is willing to give to each of the Alpha planets. You must then figure out the total amount that goes to Alpha I, and the total amount that goes to Alpha II. Then, convert the money to the proper bases for Alpha I and Alpha II, and give it to Alpha I and Alpha II.

When the Federation assigned you to this mission, you were given the following information:

Omega I is willing to give 211_3 units to Alpha I
Omega I is willing to give 211_3 units to Alpha II
Omega II is willing to give 52_{10} units to Alpha I
Omega II is willing to give 52_{10} units to Alpha II
Omega III is willing to give 333_{-4} units to Alpha I
Omega III is willing to give 333_{-4} units to Alpha II

Alpha I's monetary system is in base 6. Alpha II's monetary system is in base -8.

How much will each planet receive in its own base?

APPENDIX D

IMMEDIATE AND DELAYED TESTS FOR TASK A

Immediate Test

Please show all your work, including equations. Your score will be the number of correct steps in your solution.

At the same Las Vegas Casino, you want to try your luck at another game. You have to do two things. One is to draw a card from a deck of 52 playing cards. The other is to spin a pointer that has eight different colors. Each color is equally likely. You win $10 if the card you draw is the 10 of Diamonds or if the pointer lands on green. Otherwise you win nothing. What is the expected value of the game?

Delayed Test

Please show all your work, including equations. Your score will be the number of correct steps in your solution.

Suppose you want to play a gambling game at a Las Vegas Casino. In this game you have to throw an honest six-sided die, and draw a card from a deck of 52 playing cards. You win the jackpot of $1000 if you throw a six on the die or if the card is the Ace of Hearts. Otherwise you win nothing. What is the expected value of this game?

APPENDIX E

IMMEDIATE AND DELAYED TESTS FOR TASK B

Immediate Test

Find the formula for the nth triangular number.

(Formulas you may want to use:

$$\text{nth term} = a + (n-1)d$$

$$\text{sum} = \frac{(1\text{st} + \text{nth})}{2} \times n \quad .)$$

Please show all your work, including diagrams. Your score will be the number of correct steps in your solution.

Delayed Test

Find the formula for the nth square number.

(Formulas you may want to use:

$$\text{nth term} = a + (n-1)d$$

$$\text{sum} = \frac{(1\text{st} + \text{nth})}{2} \times n \quad .)$$

Please show all your work, including diagrams. Your score will be the number of correct steps in your solution.

APPENDIX F

IMMEDIATE AND DELAYED TESTS FOR TASK C

Immediate Test

Please show all your work, including charts and scratchwork. Your score will be the number of correct steps in your solution. You can receive credit only for steps that you write down.

It is now a year after your return from your mission aboard the Starship Enterprise. Federation Headquarters has asked you to return to the planetary system of Omega I, II, and III, and Alpha I and II. Omega I, II, and III have agreed to give more money to Alpha I and II for damages.

You must first collect the money that each of the Omega planets is willing to give to each of the Alpha planets. You must then figure out the total amount that goes to Alpha I, and the total amount that goes to Alpha II. Then convert the money to the proper bases for Alpha I and II. Alpha I's money is in base 6. Alpha II's money is in base -8.

You have the following information for your mission:

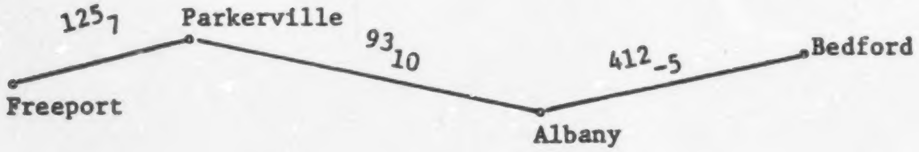
Omega I will give 112_3 units to Alpha I
Omega I will give 112_3 units to Alpha II
Omega II will give 95_{10} units to Alpha I
Omega II will give 95_{10} units to Alpha II
Omega III will give 212_{-4} units to Alpha I
Omega III will give 212_{-4} units to Alpha II

How much will Alpha I receive in its own base? How much will Alpha II receive in its own base?

Delayed Test

Please show all your work, including charts and scratchwork. Your score will be the number of correct steps in your solution. You can receive credit only for steps that you write down.

You are trying to get from Freeport to Bedford by rented car. But you have a very peculiar map. It marks the distances between cities in different bases.



To make matters worse, the car has two meters which show the mileage. One meter is in base 8; the other is in base -9. What will each meter read when you get to Bedford? (Assume that both meters are at zero at the start of the trip.)

APPENDIX G

PROCEDURE FOR COMPUTING THE DISTRIBUTION-FREE CONFIDENCE INTERVAL FOR β: β^*_L, β^*_U

(From Theil, 1950, and Sen, 1968)

For every pair of subjects (i, j) form $s_{ij} = \frac{y_j - y_i}{x_j - x_i}$ for $x_j > x_i$.

An s_{ij} is the slope of the line connecting a pair of points (x_i, y_i) and (x_j, y_j).

Order the N values of s_{ij} from $s^{(1)}$ to $s^{(N)}$ (largest). N attains its maximum value of $\frac{n(n-1)}{2}$ when there are no tied x values (n is the number of cases).

Form $$C_\alpha \approx z_{(\alpha/_2)} \left[\frac{n(n-1)\ (2n+5) - \sum_{k=1}^{a_n} u_k(u_k-1)\ (2u_k+5)}{18}\right]^{1/2}.$$

where n = number of cases

a_n = number of tied sets of x

u_k = number of tied elements in set k.

The upper and lower bounds of the confidence interval are

$\beta^*_U = S^{[1/2(N+C_\alpha)+1]}$ and $\beta^*_L = S^{[1/2(N-C_\alpha)]}$.

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